

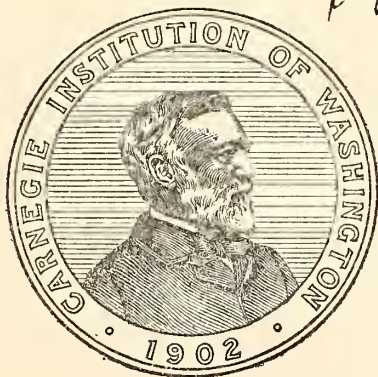
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CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 23

NOVEMBER 1, 1923, TO JUNE 30, 1924

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 12, 1924



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Director's Office*

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JOHN C. MERRIAM, *President*.

BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*.

CHARLES D. WALCOTT, *Vice-Chairman*.

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EXECUTIVE COMMITTEE: ELIHU ROOT, *Chairman*; JOHN J. CARTY, W. CAMERON FORBES, JOHN C. MERRIAM, WM. BARCLAY PARSONS, STEWART PATON, HENRY S. PRITCHETT, HENRY WHITE.

FINANCE COMMITTEE: HENRY S. PRITCHETT, *Chairman*; WM. BARCLAY PARSONS, GEORGE W. WICKERSHAM.

AUDITING COMMITTEE: R. S. BROOKINGS, *Chairman*; MARTIN A. RYERSON, GEORGE W. WICKERSHAM.

FORMER PRESIDENTS.

*DANIEL COIT GILMAN,

1902-04

*ROBERT SIMPSON WOODWARD, 1904-20

FORMER TRUSTEES.

*ALEXANDER AGASSIZ, 1904-05
*JOHN S. BILLINGS, 1902-13
*JOHN L. CADWALADER, 1903-14
CLEVELAND H. DODGE, 1903-23
*WILLIAM E. DODGE, 1902-03
CHARLES P. FENNER, 1914-24
SIMON FLEXNER, 1910-14
*WILLIAM N. FREW, 1902-15
LYMAN J. GAGE, 1902-12
*DANIEL C. GILMAN, 1902-08
*JOHN HAY, 1902-05
*ABRAM S. HEWITT, 1902-03
*HENRY L. HIGGINSON, 1902-19
*ETHAN A. HITCHCOCK, 1902-09
*HENRY HITCHCOCK, 1902-02
*WILLIAM WIRT HOWE, 1903-09

*CHARLES L. HUTCHINSON, 1902-24
*SAMUEL P. LANGLEY, 1904-06
*WILLIAM LINDSAY, 1902-09
*HENRY CABOT LODGE 1914-24
*SETH LOW, 1902-16
*WAYNE MACVEAGH, 1902-07
*S. WEIR MITCHELL, 1902-14
GEORGE W. PEPPER, 1914-19
*JOHN C. SPOONER, 1902-07
WILLIAM H. TAFT, 1906-15
HENRY P. WALCOTT, 1910-24
*ANDREW D. WHITE, 1902-16
*EDWARD D. WHITE, 1902-03
*ROBERT S. WOODWARD, 1905-24
*CARROLL D. WRIGHT, 1902-08

*Deceased.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS

Department of Embryology:

Established 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director.
CHESTER H. HEUSER.
MARGARET R. LEWIS.

W. H. LEWIS.
A. H. SCHULTZ.

Department of Genetics:

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

CHARLES B. DAVENPORT, Director.
A. F. BLAKESLEE, Assistant Director.
H. H. LAUGHLIN, Assistant Director.
H. J. BANKER.
A. M. BANTA.
JOHN BELLING.

A. H. ESTABROOK.
M. DEMEREC.
J. A. HARRIS (Resigned).
E. C. MACDOWELL.
C. W. METZ.
OSCAR RIDDLE.

Geophysical Laboratory:

Organized 1906, opened 1907.

ARTHUR L. DAY, Director.
L. H. ADAMS.
EUGENE T. ALLEN.
N. L. BOWEN.
C. N. FENNER.
R. E. GIBSON.
J. W. GREIG.
MARY G. KEYES.
F. C. KRACEK.
R. H. LOMBARD.
H. E. MERWIN.
G. W. MOREY.

EUGEN POSNJAK.
H. S. ROBERTS.
E. S. SHEPHERD.
F. HASTINGS SMITH.
ROBERT B. SOSMAN.
H. S. WASHINGTON.
WALTER P. WHITE.
*E. D. WILLIAMSON.
FRED E. WRIGHT.
R. W. G. WYCKOFF.
E. G. ZIES.

* Died December 25, 1923.

Department of Historical Research:

Organized 1903; Andrew C. McLaughlin, Director 1903-1905.

J FRANKLIN JAMESON, Director.
EDMUND C. BURNETT.
FRANCES G. DAVENPORT.
MARY F. GRIFFIN.

WALDO G. LELAND.
CHARLES O. PAULLIN.
LEO F. STOCK.

Department of Meridian Astrometry:

Established 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director.
SEBASTIAN ALBRECHT.
SHERWOOD B. GRANT.
HEROY JENKINS.

HARRY RAYMOND.
ARTHUR J. ROY.
W. B. VARNUM.
RALPH E. WILSON.

Mount Wilson Observatory:

Established 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director.
WALTER S. ADAMS, Director.
ALFRED H. JOY, Secretary.
F. H. SEARES, Supt. Computing Division.
A. S. KING, Supt. Physical Laboratory.
J. A. ANDERSON.
HAROLD D. BABCOCK.
FERDINAND ELLERMAN.
EDWIN P. HUBBLE.
MILTON HUMASON.

PAUL W. MERRILL.
SETH B. NICHOLSON.
FRANCIS G. PEASE.
EDISON PETTIT.
R. F. SANFORD.
SINCLAIR SMITH.
GUSTAF STRÖMBERG.
CHARLES E. ST. JOHN.
A. VAN MAANEN.

INVESTIGATORS—*continued*.*Nutrition Laboratory:*

Organized 1907; opened 1908.

FRANCIS G. BENEDICT, Director.
T. M. CARPENTER.
E. L. FOX.

E. S. MILLS.
P. P. SAPONARO.

Laboratory for Plant Physiology:

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905.
Name changed to Laboratory for Plant Physiology in 1923.

DANIEL T. MACDOUGAL, Director.
WILLIAM A. CANNON.
J. M. MCGEE.

FORREST SHREVE.
H. A. SPOEHR.
GODFREY SYKES.

Department of Terrestrial Magnetism:

Organized 1904.

LOUIS A. BAUER, Director.
J. A. FLEMING, Assistant Director.
J. P. AULT.
D. G. COLEMAN.
C. R. DUVAL.
H. M. W. EDMONDS.
C. C. ENNIS.
H. W. FISK.
O. H. GISH.
R. H. GODDARD.
JOHN W. GREEN.
J. T. HOWARD.

H. F. JOHNSTON.
C. M. LITTLE.
W. A. LOVE (Resigned).
S. J. MAUCHLY.
W. C. PARKINSON.
W. J. PETERS.
J. SHEARER (Resigned).
A. THOMSON.
O. W. TORRESON.
G. R. WAIT.
W. F. WALLIS.

Tortugas Laboratory:

Department of Marine Biology, organized in 1903; Alfred G. Mayor, Director 1903-1922.

INVESTIGATORS AT TORTUGAS LABORATORY, SUMMER 1924.

PAUL BARTSCH (U. S. National Museum).
CASWELL GRAVE (Washington University).
WILLIAM H. LONGLEY (Goucher College).
SERGIUS MORGULIS (University of Nebraska).
HENRY F. PRATT (Haverford College).

ASA A. SCHAEFFER (University of Kansas).
WALDO L. SCHMITT (U. S. National Museum).
C. V. TAYLOR (University of California).
W. R. TAYLOR (University of Pennsylvania).
D. H. TENNENT (Bryn Mawr College).

Ecological Research:

FREDERIC E. CLEMENTS, Associate.
G. W. GOLDSMITH.
H. M. HALL.

FRANCES L. LONG.
J. V. G. LOFTFIELD.

Middle American Archaeological Research:

SYLVANUS G. MORLEY, Associate.
MONROE AMSDEN.
FRANS BLOM.

J. O. KILMARTIN.
EARL H. MORRIS.
O. G. RICKETSON jr.

Physiological Chemistry.

T. B. OSBORNE, Research Associate (Connecticut Agric. Exper. Station).
L. B. MENDEL, Research Associate (Yale University).

A. J. WAKEMAN.
C. S. LEAVENWORTH.
HELEN CANNON.
H. B. VICKERY.

Biology:

T. H. MORGAN, Research Associate (Columbia University).

C. B. BRIDGES.
A. H. STURTEVANT.

INVESTIGATORS—*continued.**Fellows of Institution:*

SAMUEL F. BEMIS, History.
 BEVERLY L. CLARKE, Plant Physiology.
 FRANKLIN F. SNYDER, Embryology.
 PAUL P. STOUTENBURGH, Geophysics.
 F. H. FROST, Palæontology.

Other Investigators:

S. J. BARNETT, Research Associate in Physics.
 HENRY BERGEN, Research Associate in Early English Literature.
 RALPH W. CHANEY, Research Associate in Palæobotany.
 OLIVER P. HAY, Associate in Palæontology.
 ELIAS A. LOWE, Associate in Palæography.
 ALBERT MANN, Research Associate in Biology.
 GEORGE SARTON, Associate in the History of Science.
 ESTHER B. VAN DEMAN, Associate in Roman Archæology.
 GEORGE R. WIELAND, Associate in Palæontology.
 HARRY O. WOOD, Research Associate in Seismology.

Additional Research Associates Connected with other Institutions:

S. J. MCINTOSH ALLEN (University of Cincinnati), Terrestrial Magnetism.
 CARL BARUS (Brown University), Physics.
 GREGORY P. BAXTER (Harvard University), Chemistry.
 V. BJERKNES (University of Bergen, Norway), Meteorology.
 W. E. CASTLE (Harvard University), Biology.
 HENRY E. CRAMPTON (Columbia University), Biology.
 T. C. CHAMBERLIN (University of Chicago), Geology.
 W. J. CROZIER (Rutgers University), Biology.
 A. L. DU TOIT (South Africa), Geology.
 H. D. FISH (University of Pittsburgh), Zoology.
 E. NEWTON HARVEY (Princeton University), Biology.
 JOHN F. HAYFORD (Northwestern University), Physics.
 J. H. JEANS (Royal Society of London), Astronomy.
 WALDEMAR JOCHELSON (Sweden), Archæology.
 A. E. KENNELLY (Harvard University), Terrestrial Magnetism.
 C. A. KOFOID (University of California), Zoology.
 B. E. LIVINGSTON (Johns Hopkins University), Botany.
 A. O. LEUSCHNER (University of California), Astronomy.
 ISABEL MCCrackEN (Stanford University), Biology.
 A. A. MICHELSON (University of Chicago), Astronomy.
 R. A. MILLIKAN (California Institute of Technology), Physics.
 FRANK MORLEY (Johns Hopkins University), Mathematics.
 E. L. NICHOLS (Cornell University), Physics.
 A. A. NOYES (California Institute of Technology), Chemistry.
 W. J. V. OSTERHOUT (Harvard University), Botany.
 T. W. RICHARDS (Harvard University), Chemistry.
 ROBERT W. ROGERS (Drew Theological Seminary), History.
 HENRY N. RUSSELL (Princeton University), Astronomy.
 H. C. SHERMAN (Columbia University), Chemistry.
 EDGAR F. SMITH (University of Pennsylvania), Chemistry.
 GRAHAM H. STUART (Stanford University), Political Science.
 LEWIS H. WEED (Johns Hopkins University), Anatomy.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. * The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees herein-after appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES
OF THE
TWENTY-FIFTH MEETING OF THE BOARD OF
TRUSTEES

ABSTRACT OF MINUTES OF THE TWENTY-FIFTH MEETING OF
BOARD OF TRUSTEES.

The meeting was held in Washington in the Board Room of the Administration Building, on Friday, December 12, 1924, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, W. Cameron Forbes, Herbert Hoover, Andrew J. Montague, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, William H. Welch, Henry White, George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the twenty-fourth meeting were approved as printed and submitted to the members of the Board.

The Secretary reported that the Board had sustained losses during the past year by reason of the deaths of Mr. Hutchinson, of Mr. Lodge, and of Mr. Woodward, and that a fourth vacancy existed by reason of the resignation of Mr. Dodge.

The resignations of Charles P. Fenner and Henry P. Walcott as members of the Board were presented and accepted with regret.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1925 were authorized:

Insurance Fund.....	\$5,500
Pension Fund.....	40,000
Administration.....	65,500
Publication (including Division of Publications).....	92,500
Departments and Divisions of Research.....	964,773
Minor Grants.....	161,300
Index Medicus.....	10,000
General Contingent Fund.....	45,000

1,384,573

Upon ballot Cass Gilbert, of New York, Frederick H. Gillett, of Massachusetts, Andrew W. Mellon, of Pennsylvania, and William Benson Storey, of Chicago, were unanimously elected as Trustees of the Institution to fill vacancies caused by the resigna-

tion of Mr. Dodge, and the deaths of Mr. Hutchinson, Mr. Lodge, and Mr. Woodward.

The following officers of the Board and the following members of committees were re-elected for a period of three years:

Officers of the Board: Chairman, Mr. Root; Vice-Chairman, Mr. Walcott; Secretary, Mr. Forbes.

Members of the Executive Committee: Messrs. Parsons, Paton, and Pritchett.

Members of the Finance Committee: Mr. Parsons, Mr. Pritchett (chairman), Mr. Wickersham.

Members of the Auditing Committee: Mr. Brookings (chairman), Mr. Wickersham.

Mr. Ryerson was elected a member of the Auditing Committee in place of Mr. Hutchinson.

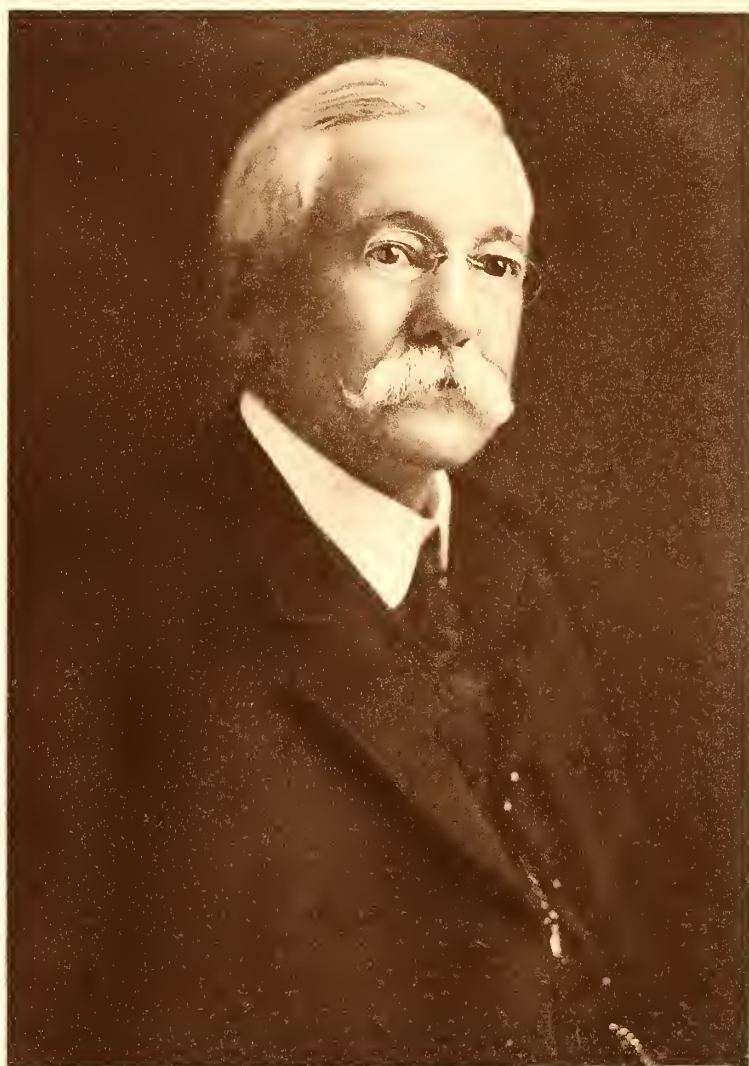
The meeting adjourned at 12^h10^m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1924



Robert S. Woodward

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report for the fiscal year ending October 31, 1924, together with a statement regarding future development of the Institution.

During the past year we have lost from the membership of the Board of Trustees three of the persons who have been most active in development of the work of the Institution. Mr. Cleveland H. Dodge, a member since 1903, found it necessary to sever his connection with the Board by reason of ill-health. Mr. Dodge served with distinction as Secretary of the Board of Trustees and as a member of the Executive Committee for the period from 1905 to 1922, and it was with great regret that his resignation was accepted.

It is with sorrow that I must report in this year's review the loss by death of two members, Dr. Robert S. Woodward and Mr. Charles L. Hutchinson.

Dr. Robert Simpson Woodward, for sixteen years President of the Carnegie Institution of Washington, died at his home in Washington on June 29, 1924, at the age of seventy-five years.

Robert S. Woodward.	His death ended a lingering illness of nineteen months following an attack of influenza.
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Dr. Woodward was born in Rochester, Michigan, on July 21, 1849, his father being a farmer with a deep interest in public affairs. The interest in agriculture developed in boyhood was maintained through life, and in later years he found recreation in operating a farm in Montgomery County, Maryland. Entering the University of Michigan, he received the degree of civil engineer from that institution in 1872. In the same year he was appointed assistant engineer on the United States Lake Survey Commission, a position which he held for ten years.

Upon completion of his service in the Lake Survey Dr. Woodward was appointed assistant astronomer on the United States Transit of Venus Commission, which was an evidence of his ability as mathe-

matician and engineer; it was also an indication of the inherent love for astronomical and astrophysical problems shown by numerous contributions to astronomical journals. After completing service with this body, he was made astronomer of the United States Geological Survey in 1884, holding successively in the following six years the positions of astronomer, geographer, and chief geographer.

Still pursuing a clear preference for mathematical and physical work of high precision, Dr. Woodward went from the Geological Survey to the Coast and Geodetic Survey in 1890. While there he received appointment in 1893 as professor of mechanics and mathematical physics in Columbia University, New York City. He became Dean of the School of Pure Science of the University in 1895 and held that position until 1905, when he was made President of the Carnegie Institution.

During his period of service as an educator Dr. Woodward presented to his students and colleagues the highest ideals and at the same time the most practical view of their use. Constructive thought was always given first place, as when he stated that "those who can add somewhat to the sum and substance of permanent knowledge by the establishment of a physical, a social, an aesthetic, or an ethical principle, are the greatest benefactors of our race." Never did he hesitate to take a strong stand upon questions of fundamental principle which might be under discussion. He once described the method of science as "having permeated all regions of thought and animated all of the commercial, industrial, political, social, and religious activities of men. Whether we welcome it, deplore it, or indifferently acquiesce in it, the fact seems undeniable that the method of science and the doctrine of evolution are the most effective sources of the intellectual enterprise of our day."

Dr. Woodward's record in the field of scientific activity is impressive and the list of papers published by him includes contributions to higher mathematics, physics, and geophysics. The significance of the interrelation of these subjects as they were visualized by him is shown in one of his best-known papers which treats of the figure, distribution of density, and the cooling rate of the earth.

Selected in 1904 as the man best qualified to succeed Dr. Daniel Coit Gilman, the first President of the Institution, Dr. Woodward brought to this work constructive thought and mental vigor which have contributed largely toward establishing the Institution on a basis justifying the organization of research for specific attack on major problems. At the time he became President the plan of administration was necessarily only in tentative operation and the question was

REPORT OF THE PRESIDENT, 1924.

imminent whether it would prove more effective to place sums of money in the hands of investigators to expend as seemed to them wisest, without further responsibility for method of use, or whether departments of research might be established in which the expenditure of funds should remain under control of the Trustees. After a number of trials the latter policy was in general adopted early in Dr. Woodward's administration.

Many institutions and learned bodies, both in America and in foreign lands, honored Dr. Woodward. He was a member of the National Academy of Sciences, President of the American Association for the Advancement of Science (1900-01), and its Treasurer from 1894 until his death. He was President of the New York Academy of Sciences (1900-02), President of the American Mathematical Society (1898-1900), and served throughout the Great War as a member of the Naval Consulting Board.

Mr. Charles L. Hutchinson died on October 7, 1924, after a brief illness due to bronchial pneumonia. Mr. Hutchinson was one of the original Board of Trustees named in 1902 by Mr.

**Charles L.
Hutchinson.**

Carnegie to guide the affairs of the Institution.

He will be remembered as a man of most engaging personality, a philanthropist and benefactor of strong sympathies and high integrity. Possessing unusual business acumen, he was made President of the Corn Exchange National Bank and of the Chicago Board of Trade. At the time of his death he was Vice-President of the Illinois Merchants Trust Company.

In addition to his important contribution through commercial activities, Mr. Hutchinson's support to movements touching the betterment of ideals and of opportunities for enlightenment made him an outstanding figure in the life of Chicago. He was interested in civic and charitable pursuits and found particular enjoyment in studies concerning literature, art, and music. He was founder and at one time president of the Art Institute of Chicago, treasurer of the University of Chicago, president of the Chicago Orphans Asylum, a trustee of Hull House, and a director of the Presbyterian Hospital.

Mr. Hutchinson was an able supporter of such enterprises in the field of humanistic studies as it was possible for the Carnegie Institution to undertake. At all times he was a strong advocate of the policy of keeping the work of the Institution on a sound financial basis with a view to securing the largest possible positive results in constructive research.

CARNEGIE INSTITUTION OF WASHINGTON.

The mere attempt to present an outline of significant work under way in the Institution in the year just ended carries the risk of diverting attention from the extraordinary series of departmental and individual reports. While the Year Book for 1924 is naturally made up in large part of statements relating to technical progress in researches, the briefest review of accomplishment by the departments and individuals reveals a wealth of outstanding problems and a record of extraordinary achievement in their investigation.

Year Book
Report on
Research
Activities.

In addition to the detailed account of individual efforts, the record of each department, viewed as a unit, commands attention as evidence of development of plans requiring cooperation of many mutually supporting researches. Such are, among others, the programs of the Department of Embryology, or the Geophysical Laboratory, or those of the two divisions of the Institution relating to astronomical work, namely, Mount Wilson Observatory and the Department of Meridian Astrometry. In the Department of Embryology one sees the human embryo considered not from every point of view but from its most significant aspects; these comprise development of the individual types of tissue, morphological study of the various systems of the body ranging from skeleton to nervous system, comparative morphology and physiology, important relations to pathology, and in the work of Dr. Schultz they reach to the significance of racial characteristics in early developmental stages. It is through such an organized attack that it becomes possible for the Institution to make the most rapid and most certain advances in the special subjects which it investigates.

Without intending to segregate a list of outstanding achievements in the past year's work, it is interesting to note certain types of progress characterizing this period.

Advances
Characteristic
of the Year's
Work.

As in every other year, the striking evidences of progress have ranged from development of instrumental equipment to advances in interpretation and theory. The new type of seismometer recently constructed by Dr. Anderson of Mount Wilson Observatory has been tested and refined. As a result it gives even larger promise of service in fundamental earthquake investigation than was indicated at the time of first announcement. In addition to this instrument, Dr. Anderson is constructing apparatus which will go far in assisting to measure strains in the earth's crust.

REPORT OF THE PRESIDENT, 1924.

In the equipment at Mount Wilson Observatory an important addition is made to the possibilities for research by the building of a solar laboratory—a gift to the Institution by Dr. Hale, to be used in the extension of his epoch-making studies.

In the Geophysical Laboratory Dr. Fred E. Wright has produced a new instrument for measuring the force of gravity. The relative simplicity and easy manipulation of this apparatus promise to make it extremely valuable in advancing knowledge of conditions in the earth's crust which are critical in a study of the physical properties of the earth as a whole.

In still another direction a very interesting and significant investigation, dependent in large measure upon instrumental development, is that of Dr. Michelson, who, as Research Associate of the Institution at Mount Wilson Observatory, has made an extremely important advance in redetermination of the velocity of light.

In a widely distant field of research, Dr. Schultz of the Department of Embryology has opened the way for new comparative studies through securing embryonic material of American monkeys on a difficult expedition into the forests of Central America.

Another group of investigators, representing the Advisory Committee on Human Behavior, spent the summer in behavior studies of a great collection of apes and monkeys kindly placed at their disposal by Madam Abreu of Havana.

In another phase of biological work Dr. Blakeslee of the Department of Genetics has been able to expand the opportunity for his critical investigations of heredity in the jimson weed through an increase of approximately fifty per cent in the greenhouse space used for this work. Dr. Blakeslee is extending his studies in still another way by visiting Cuba and South America for examination of these plants under natural conditions. In the same laboratory Dr. Riddle has made noteworthy progress in research on influence of glands in control of development. Dr. Laughlin of the Eugenics Record Office has at the same time been contributing largely to the strictly tested scientific data regarding heredity in the horse. In few investigations of the higher animals has there been so large a body of carefully assembled data available bearing on a problem of heredity.

In the Laboratory for Plant Physiology at Carmel Dr. Spoehr, by continued refinement of his methods, has brought us distinctly nearer to an understanding of the influence of sunlight in the chemical processes of the plant.

CARNEGIE INSTITUTION OF WASHINGTON.

On the side of theoretical considerations, the Department of Terrestrial Magnetism has been engaged in the extremely difficult and interesting task of working toward interpretation of the material assembled through its exceptionally efficient observational work. In the conduct of these studies a number of distinguished investigators have been in association with Dr. Bauer and the staff. The questions considered in this attack rank among the most difficult in the field of physical research and every effort is being made to bring to bear the means available for their solution.

Without multiplying examples of advances made within the past year, I wish only to add that the group of investigators associated with the Institution has been giving the best that concentration of purpose and devotion to a good cause can offer in the attempt to learn more fully the real meaning of the Universe in which we live. Their searching ranges from the secret places of the earth to the outer limits of the remotest heavens, but it is done with clear vision. That which they discover, however strange it may seem, is only a more truthful expression of reality in the world about us than has heretofore been recognized.

During the year Frans Blom and O. G. Ricketson Jr. continued the archaeological studies conducted by the Institution in Guatemala, giving special attention to investigation of the ancient Maya city of Uaxactun. Important discoveries were also made in British Honduras through the work of Mr. Ricketson.

Intensive
Historical
Research in
Middle America.

The plan for intensive archaeological research in Middle America, first proposed in 1913 and discussed in the annual reports of past years, was put into active operation in the spring and summer of 1924. Although the beginning of field work in the city of Chichen Itzá in Yucatan was delayed, most gratifying success resulted from the initial excavation at the site of the Thousand Columns area. Under the able handling of Earl Morris the excavations have brought out a most interesting and important series of structures. The progress made this year indicates that the Thousand Columns area will prove a very attractive and profitable field for research as the investigation proceeds.

In the course of this year it has been possible to complete the first clearly marked unit of the work, this being a special map of the City of Chichen Itzá, prepared by J. O. Kilmartin, who was permitted to cooperate with the Institution through courtesy of the Topographic

REPORT OF THE PRESIDENT, 1924.

Branch of the United States Geological Survey. The fine expression of location and contour of the visible ruins makes this a classic document and an invaluable guide for all future work.

In connection with the program for study in the field of Middle American Archaeology, it has been gratifying to have a series of lectures, on fundamental problems in the archaeology of Mexico, delivered before the Institution in April, 1924, by Dr. Manuel Gamio, Director of the Dirección de Antropología of Mexico. Dr. Gamio's visit to the Institution was made the occasion of an important conference on archaeological problems of Mexico. The participation of Dr. Gamio and of the group of American students who conferred with him on this occasion has contributed much toward advancement of cooperation in archaeological studies of Middle America. It is hoped that further conferences of this nature may be held at the scene of the excavations.

With the death of Dr. Alfred G. Mayor the Institution's work in marine biology has naturally reduced itself to a narrower compass than under active management of the Director. In the course of the past two years it has been possible to bring together for publication a large part of the completed work conducted under Dr. Mayor's direction. The attempt has been made also to complete the unfinished projects which had been developed in the Department. The results so far prepared for publication are included in one volume already issued and three other volumes now in preparation for the press.

In furtherance of the researches which had been under way in this department, arrangement was made to open the laboratory at the Dry Tortugas in the Gulf of Mexico, and in the summers of 1923 and 1924 groups of investigators were in residence at the laboratory. In the season of 1924 ten research workers were present.

Certain phases of biological work on tropical marine organisms at the Tortugas Laboratory touch some of the major problems of other divisions of the Institution, as in physiology, embryology, genetics, and ecology. There is reason to believe that in the immediate future utilization of the excellent plant and facilities at this station will be productive of important results, both in completion of work on problems taken up by Dr. Mayor and in furtherance of research on special questions relating to biological studies initiated by other departments and by associated workers.

CARNEGIE INSTITUTION OF WASHINGTON.

In some respects the Carnegie Institution of Washington is a unique type of agency as to its objectives and its organization.

Unique Opportunities of the Institution.

Although the fundamental researches to which its energies are devoted may be expected ultimately to contribute more for human use and betterment than would be accomplished with the same effort expended upon immediate practical needs, the results may for the moment appear to be merely the product of organized curiosity or of an extremely refined intellectual sport.

While, in the true meaning of education, the Institution's contributions and contacts may be among the most significant of those leading to the informing, and therefore the educating, of students in the after-graduation stage, the seeming isolation of this group of workers is sometimes mistaken for aloofness. The organization of our investigations around projects, representing fields of study in which it is especially opportune to have expansion of knowledge, differs from commonly adopted plans in which a general subject such as Greek or zoology is made the area or department in which research is to be conducted.

Added to other peculiar features, the location of departments or investigators wherever their work can be carried on to best advantage has made the group of characters of this Institution still more striking. While many great organizations are to-day giving most careful thought to the suggestion that separation of their departments by the width of a city, or by only a few city blocks, may constitute an obstacle in the way of correlated effort or institutional efficiency, the map of our interests shows important agencies ranging from Boston, through Long Island, District of Columbia, California, South America, and Australia. But it should be remembered that the departments of this Institution have been located generally where they can function to best advantage. The magnetic observatories at Huancayo in Peru and Watheroo in Australia are on opposite sides of the earth because the data from opposite sides are especially desired. After much careful investigation, the site of the astronomical station on Mount Wilson was selected because of its fitness for a special work. Dr. Mayor chose the Dry Tortugas rather than Long Island because he considered it better suited to the purpose of his studies in marine biology.

While the loss due to geographic separation of related interests must be considerable, the possibilities of this plan of operation may be relatively large if close cooperation is established. One of the major

opportunities for the future of the Institution lies in just this mutual support between highly developed agencies with exceptionally favorable situation. In such unity there is an opportunity not open in the same way to other kinds of organizations.

Such cooperation has, for example, been found by conference of our investigators to be especially favorable in the field of life development including genetics, experimental evolution, ecology, embryology, nutrition, plant physiology, and marine biology. These departments, groups of investigators, and individual researchers, scattered widely over the country, are conducting some of the best organized attacks on problems relating to the nature of heredity, the development of the individual, the influence of environment, and other critical questions touching the great problem of growth or development in the life world. Individually these activities make most significant contributions to advancement of knowledge. This opportunity for expression of individual and departmental initiative is enormously important in such a field as research, concerning little-known or imperfectly understood questions and with the avowed object of discovering what is yet outside the boundaries of knowledge. But the fact that there are many points of view and differences in location and environment of the agencies represented makes possible, through the flexible organization of the Institution, a kind of study of these questions which would be much more difficult by other methods of attack. It may be that the way is now open for a much larger realization of result for each and all than has heretofore been within reach. Such advance would necessarily involve also the closest relation to those agencies outside the Institution with which there can be advantageous cooperation.

The peculiarities of the Institution as to purpose, organization, and location open possibilities for ultimate diminishing of its usefulness if it is operated in the same manner as other bodies with somewhat different aims and structure. If we conduct our work on the plans best fitted to our real aims the admitted disadvantages may be in considerable measure overcome, and many apparent handicaps will be found blessings only moderately disguised—Dr. Adams in his work at Mount Wilson found that just because the absolute magnitude of stars is disguised by distance, the discovery of new means for determining the absolute magnitude made it possible to estimate the distance. This gave a method which opened the way for great advances in our knowledge of the universe. So, with careful study of our problem of organization, we will learn ultimately to turn what seems like adversity to advantage.

CARNEGIE INSTITUTION OF WASHINGTON.

The period of the annual meeting with accompanying conferences and exhibits of current work is increasingly important. The exhibition of results secured through researches supported by the Institution gives in one picture the best view we have of progress in the year. The opportunity for members of the staff to know the work of departments with which close contact is prevented by geographic separation becomes more significant as we see the value of combined effort of divisions of the Institution on certain investigations. Both examination of results and discussion of problems with the investigator are certain to open the way for cooperation to mutual advantage.

As the occasion of the annual meeting is in close proximity to the time of the large group of scientific gatherings at the end of the year, it is often possible to use this period of conferences to advantage in developing contacts with other institutions and agencies engaged in research on problems related to those with which we are immediately concerned.

The plan for bringing a body of able young investigators into contact with work of the Institution, through the establishment of fellowships, has proved valuable in several departments ranging from history to geophysics. It is gratifying to find that by means of this relation we may receive the stimulus of new interests and of new viewpoints of students entering the field of investigation. It is also interesting to note that in moving from the Institution holders of fellowships have gone to important research positions, in which they may continue in close touch with our work.

Since it is the purpose of the Institution to devote itself to fundamental aspects of research, it is to be expected that the results secured will be mainly in the form of technical statements and discussions representing the farthest limit of human experience in advancing knowledge in special fields. The publications issued directly by the Institution, and the special articles appearing through other channels, will naturally be expressions of such technical material. These contributions go into the hands of other investigators, to educators, and to those applying knowledge in technical pursuits. In this manner the principal products of our work reach the stream of knowledge drawn upon by the community.

In addition to publication of technical papers, many members of the staff of the Institution are concerned with the philosophic significance of the investigations and present to the public through discussion before scientific bodies, through articles of general appeal,

REPORT OF THE PRESIDENT, 1924.

by lectures, and in many other ways, the interpretation of these technical results. Some of the significant contributions to knowledge arising through work of our investigators have been discussed in most admirable fashion in the Institution's lectures delivered in Washington in the past three years. More recently, by brief but carefully prepared statements, the effort has been made to make some of the most important discoveries or results of research available to the public through the press in such form that they may be intelligible to the general reader.

After nearly four years' trial of a modified system for distribution of our publications, we are now making a restudy of the effectiveness of this method. It must naturally be our purpose to place copies where they can be of largest service both now and in the future. In carrying out such a plan there is involved on the one hand the factor of economy, inasmuch as funds saved from one publication become available for further research or the issuing of additional research results; on the other hand it is clearly recognized that wise expenditure of funds requires most careful study of dissemination of information after the investigations are completed.

In the course of the past year the following public lectures have been delivered in the Administration Building at Washington:

Lectures.

November 20, 1923. "The Approach to Diplomatic History illustrated by the Correspondence of the Early British Ministers to the United States," by Dr. J. Franklin Jameson, Director of the Department of Historical Research.

November 27, 1923. "Cooperative Earthquake Studies in California," by Dr. Arthur L. Day, Director of the Geophysical Laboratory.

April 16, 1924. "Anthropology in Mexico—Present Knowledge and Suggestions for Future Development," by Dr. Manuel Gamio, head of the Dirección de Antropología of the Government of Mexico.

April 17, 1924. "Suggested Methods for Archaeological Investigations in Mexico," by Dr. Manuel Gamio.

May 1, 1924. "Sunlight—the Prime-Mover of Civilization," by Dr. H. A. Spoehr, of the Laboratory for Plant Physiology.

October 28 and 29, 1924. "Initial Excavations by the Institution at Chichen Itzá, Yucatan," by Dr. Sylvanus G. Morley, Associate of the Institution in Middle American Archaeology.

It is gratifying to report evidences of confidence in the work of the Institution expressed in the course of the past year through a number of

. Gifts for
Support of
Research
Projects.

important gifts for support of researches. These funds have been contributed partly for investigations already under way, partly for developing projects in which additional money could be used advantageously, and in several instances they have been given for new undertakings which could be carried out to special advantage through the medium of the scientific staff and organization of the Carnegie Institution.

Though the Institution is living within its income, with such margin as is required for emergencies, it should be noted that concurrent with the widening of its opportunity for constructive work in the past decade there has been large increase in the cost of research. That the Institution has been able to keep its position among scientific agencies, in spite of what has amounted to a gradually diminishing income, is due to the foresight of the Trustees in the early period of development and to the well-organized and effective efforts of departments and individual investigators.

Financial
Provision for
Continuing
Development.

There can be little doubt that the trend both of expenditure and of opportunity for accomplishment so clearly shown in the history of the Institution indicates in a general way the probabilities for the next generation. Mr. Carnegie had a vision of the need for research when the Institution was founded. He realized that a period of utilization of great natural resources would be followed by a stage in which intensified investigation of materials, and of methods, would be necessary if the normal progress of civilization be continued. The situation Mr. Carnegie saw is now being realized. It is also clear that the present advance of constructive work is a mere beginning compared with requirements of the future. The opportunity for service by the Institution through contribution in fundamental research will be greatly increased. There is every indication that at the same time we may expect diminishing purchasing power of the resources upon which our work is dependent. If the Institution is to continue serving in a measure corresponding to what it has given heretofore, it is essential that some plan be developed by which its resources can be increased, at least to an extent comparable to the reduction in purchasing power.

By reason of the kind of attack which this organization makes upon research problems, it lacks those means for enlarging income which are available to most agencies concerned with advancement of knowledge. We do not have a rapidly growing body of supporters with the intimate relation expressed in the alumni of educational institutions, nor do we have the possibility of added income arising through modification of tax rate as in government-supported agencies. Unless the Institution allows itself to become dependent for its advance upon continually increasing gifts, a method must be devised by which, through regular addition to endowment, a growing interest return or income can be secured for support of regular operations. Even if considerable funds were obtained by gift, it would be desirable to add a large part if not all of the interest from such sums to endowment and to use for operating expenses only the interest upon such additions.

REPORT OF THE PRESIDENT, 1924.

Without external assistance, a beginning can be made by so organizing our program as to permit adding a moderate amount to endowment each year, thus slowly increasing the income. However difficult it might seem to put such a plan into operation at a time when larger funds could be expended to advantage, it would be better to suffer the temporary discomfort incident to such readjustment, and build for a developing program, than to face the certainty of diminishing effectiveness.

FINANCIAL STATEMENTS.

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees December 14, 1923, and revertsments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in table A.

A.—Financial statement for fiscal year ending October 31, 1924.

	Balances unallotted Oct. 31, 1923.	Trustees' appropria- tion Dec. 14, 1923.	Revert- ments and transfers Nov. 1, 1923, to Oct. 31, 1924.	Total available 1924.	Executive Committee allotments 1924.	Transfers by Execu- tive Com- mittee.	Unallotted balances Oct. 31, 1924.
Large Grants:							
Laboratory for Plant Phys- iology.....		\$57,500	\$200.00	\$57,700.00	\$57,700.00		
Embryology.....		44,660	750.00	45,410.00	45,410.00		
Ecological Research.....		34,000	1,300.00	35,300.00	35,300.00		
Genetics.....		120,755	3,300.00	124,055.00	124,055.00		
Geophysical Laboratory.....		147,376	4,100.00	151,476.00	151,476.00		
Historical Research.....		40,980		40,980.00	40,980.00		
Marine Biology.....		8,320	2,500.00	10,820.00	10,820.00		
Meridian Astrometry.....		36,036	100.00	36,136.00	36,136.00		
Middle Amer. Archaeology.....		23,800	7,350.00	31,150.00	31,150.00		
Nutrition Laboratory.....		43,594		43,594.00	43,594.00		
Mt. Wilson Observatory.....		221,088	2,000.00	223,088.00	223,088.00		
Terrestrial Magnetism.....		162,335	6,204.00	168,539.00	168,539.00		
Minor Grants.....	\$1,000.00	181,000	27,698.30	209,698.30	205,045.13	\$2,500.00	\$2,153.17
Publications.....	4,337.07	95,000	8,330.01	107,667.08	89,695.31	14,500.00	3,471.77
Administration.....		64,840	1,225.00	66,065.00	66,065.00		
Insurance Fund.....		8,000		8,000.00	8,000.00		
Pension Fund.....		40,000		40,000.00	40,000.00		
General Contingent Fund.....	8,110.00	49,000	30,078.98	87,188.98	5,332.75	75,629.00	6,227.23
	13,447.07	1,378,284	95,136.29	1,486,867.36	1,382,386.19	92,629.00	11,852.17

CARNEGIE INSTITUTION OF WASHINGTON.

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by table B; the grand total of these to date is \$26,631,689.49.

B.—Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refunds on grants.	Miscellaneous items.	Total.
1902	\$250,000.00	\$9.70	.....	.....	\$1,825.52	\$251,835.22
1903	500,000.00	5,867.10	\$2,286.16	.....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	\$999.03	.....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,114,541.13	192,287.72	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,115,187.58	193,368.98	11,994.21	18,663.38	409,712.28	1,748,926.43
Total	19,874,582.35	1,710,790.52	226,184.23	209,005.16	*4,611,127.23	26,631,689.49

* Of this amount \$3,502,961.00 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918, 1921, 1922, 1923 and 1924; \$51,265.74 from the Colburn Estate in 1916; and \$995,000 from the Carnegie Corporation of New York in 1917, 1918, 1919, 1920, 1921, 1922, 1923, and 1924.

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The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor grants and payments from Pension and Insurance Funds; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution.

C.—Aggregate of expenditures.

Year ending Oct. 31.	Purchase of bonds.	Large projects.	Minor grants and payments from Pension, Insurance, and General Contingent Funds.	Publications.	Administration.	Total.
1902	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
Total	7,603,178.23	13,410,588.23	2,971,574.52	1,208,117.92	1,112,233.04	26,305,691.94

CARNEGIE INSTITUTION OF WASHINGTON.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

D.—Real estate and equipment, original cost.

Administration:		
Building, site, and equipment (Oct. 31, 1924).....		\$340,726.81
Laboratory for Plant Physiology (Sept. 30, 1924):		
Buildings and grounds.....	\$54,705.41	
Laboratory and library.....	28,058.18	
Operating appliances.....	10,951.39	
		93,714.98
Ecological Research (June 30, 1924):		
Building, Laboratory.....	7,054.88	
Library, operating.....	3,301.58	
		10,356.46
Department of Embryology (Sept. 30, 1924):		
Library.....	1,297.27	
Laboratory.....	7,540.92	
Administration.....	3,899.93	
		12,738.12
Department of Genetics (Sept. 30, 1924):		
Buildings, grounds, field.....	270,005.59	
Operating.....	19,982.42	
Laboratory apparatus.....	12,523.09	
Library.....	23,574.18	
Archives.....	45,488.90	
		371,574.18
Geophysical Laboratory (Sept. 30, 1924):		
Building, library, operating appliances.....	193,068.47	
Laboratory apparatus.....	97,939.31	
Shop equipment.....	11,788.98	
		302,796.76
Department of Historical Research (Sept. 30, 1924):		
Office.....	3,288.52	
Library.....	4,752.73	
		8,041.25
Department of Marine Biology (Sept. 30, 1922):		
Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		52,383.84
Department of Meridian Astrometry (Sept. 30, 1924):		
Apparatus and instruments.....	3,257.34	
Operating.....	3,560.60	
		6,817.94
Nutrition Laboratory (Sept. 30, 1924):		
Building, office, and shop.....	123,772.73	
Laboratory apparatus.....	26,419.09	
		150,191.82
Mount Wilson Observatory (Aug. 31, 1924):		
Buildings, grounds, road, and telephone line.....	197,493.90	
Shop equipment.....	40,842.10	
Instruments.....	513,220.97	
Furniture and operating appliances.....	166,733.07	
Hooker 100-inch reflector.....	599,679.43	
		1,517,969.47
Department of Terrestrial Magnetism (Sept. 30, 1924):		
Building, site, and office.....	207,228.50	
Vessel and survey equipment.....	178,959.52	
Instruments, laboratory, and shop equipment.....	113,994.93	
		500,182.95
		3,367,494.58

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PUBLICATIONS.

Sales of Publications and Value of those on Hand.

Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E.—Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
Total...	96,115.24	1,278.61	128,790.38

At the end of the fiscal year there are on hand 94,198 volumes of miscellaneous publications and Year Books, having a sale value of \$278,330.30; also 31,094 numbers of the Index Medicus, having a value of \$19,757.50.

CARNEGIE INSTITUTION OF WASHINGTON.

Growth and Extent of Institution's Publications. The data furnished in table F are of statistical interest in respect to the work of publication of the Institution. 486 volumes, which embrace a total of 137,829 pages of printed matter, have thus far been issued.

F.—Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the twenty-two years from 1902 to 1924.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
Total...	503	101,482	41,846	143,328

The publication of 17 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$50,000. The following list gives the titles and names of authors of the publications issued; it includes 17 volumes, with an aggregate of 4,665 octavo pages and 834 quarto pages. Fourteen additional volumes are now in press.

Publications Authorized and Issued during the Year.

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LIST OF PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON DURING THE YEAR ENDING OCTOBER 31, 1924.

- Year Book, No. 22, 1923. Octavo, xix+381 pages.
 Index Medicus, Third Series. Vol. 3, 1923. Octavo, 1, 243 pages.
- No. 248. Britton, N. L., and J. N. Rose. The Cactaceæ. Descriptions and Illustrations of Plants of the Cactus Family. Quarto in 4 volumes. Vol. IV. vii-318 pages, 37 plates, 263 text figures.
- No. 303A. Carpenter, Thorne M. Tables, Factors, and Formulas for Computing Respiratory Exchange and Biological Transformations of Energy. Octavo, 126 pages, 37 tables. Second Edition.
- No. 322A. Hay, Oliver P. The Pleistocene of the Middle Region of North America and its Vertebrated Animals. Octavo, vii+385 pages, 29 maps, 5 figures.
- No. 329. Davenport, Charles B. Body-Build and its Inheritance. (Paper No. 35, Department of Genetics.) Octavo, vi+176 pages, 9 plates, 53 figures.
- No. 332. Contributions to Embryology. Vol. XV, Nos. 72 to 77. Quarto, iii+139 pages, 19 plates, 35 text figures.
- This book contains the following papers:
- Davis, Carl L.—Description of a Human Embryo having Twenty Paired Somites. (Contribution No. 72.) 51 pages, 4 plates, 20 figures.
- Shields, Randolph T.—On the Development of Tendon Sheaths. (Contribution No. 73.) 9 pages, 1 plate, 2 figures.
- Lee, F. C.—On the Lymph-Vessels of the Liver. (Contribution No. 74.) 10 pages, 1 plate.
- Corner, G. W.—Ovulation and Menstruation in *Macacus rhesus*. (Contribution No. 75.) 29 pages, 6 plates, 2 figures.
- Traut, H. F.—The Structural Unit of the Human Kidney. (Contribution No. 76.) 18 pages, 3 plates, 1 figure.
- Heuser, C. H.—The Branchial Vessels and their Derivatives in the Pig. (Contribution No. 77.) 19 pages, 4 plates, 8 figures.
- No. 333. Miles, Walter R. Alcohol and Human Efficiency: Experiments with Moderate Quantities and Dilute Solution of Ethyl Alcohol on Human Subjects. Octavo, x+298 pages, 51 figures.
- No. 334. James, H. G. The Constitutional System of Brazil. Octavo, 276 pages.
- No. 335. Lothrop, S. K. Tulum: An Archæological Study of the East Coast of Yucatan. Quarto, vii+179 pages, 27 plates, 182 figures.
- No. 338. Stock, Leo F. Proceedings and Debates of the British Parliaments respecting North America. Vol. I, 1542 to 1688. Octavo, xx+515 pages.
- No. 339. Perret, Frank A. The Vesuvius Eruption of 1906; Study of a Volcanic Cycle. Quarto, xxx+151 pages.
- No. 341. Setchell, William A. American Samoa: Part I, Vegetation of Tutuila Island; Part II, Ethno-Botany of the Samoans; Part III, Vegetation of Rose Atoll. (Papers from the Department of Marine Biology of the Carnegie Institution of Washington, Vol. XX.) Octavo, vi+275 pages, 37 plates, 57 figures.
- No. 350. Growth in Trees and Massive Organs of Plants. Octavo, ii+116 pages, 29 figures.
 MacDougal, D. T.—Dendrographic Measurements. Pages 1-88, 1 plate, 19 figures.
 Shreve, Forrest.—The Growth Record in Trees. Pages 89-116, 10 figures.
- No. 351. Howard, W. T. Public Health Administration and the Natural History of Disease in Baltimore, Maryland, 1797-1920. Octavo, vi+565 pages.
- No. 354. Cannon, W. A. General and Physiological Features of the Vegetation of the More Arid Portions of Southern Africa, with Notes on the Climatic Environment. Octavo, viii+159 pages, 31 plates, 13 figures.
- No. 357. Jean, Frank C., and J. E. Weaver. Root Behavior and Crop Yield under Irrigation. Octavo, 66 pages, 6 plates, 24 figures.

BIBLIOGRAPHY OF CONTRIBUTIONS TO KNOWLEDGE RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS ISSUED THROUGH CHANNELS OTHER THAN THE PUBLICATIONS OF THE CARNEGIE INSTITUTION OF WASHINGTON.

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—, and A. H. JOY. Low temperature lines in the spectra of giant M-type stars. *Pubs. A. S. P.*, vol. 35, 328-329 (1923).
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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1924.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 14, 1923, the members of the Executive Committee met and organized by the election of Mr. Root as Chairman for 1924, and by voting that the Administrative Secretary of the Institution act as secretary of the Committee for the same period.

The President's report, with accompanying Year Book, gives in detail the results of the work of the Institution for the period from July 1, 1923, to June 30, 1924, and is supplemented by itemized financial statements for the fiscal year. The President also submits a report and outline of suggested appropriations for the year 1925. The Executive Committee hereby approves the report and recommendations of the President, budget estimates for next year having been provisionally approved at the meeting of the Committee of October 24, 1924.

The Board of Trustees, at its meeting of December 14, 1923, appointed F. W. Lafrentz & Company, formerly the American Audit Company, to audit the accounts of the Institution for the fiscal year ending October 31, 1924. The report of the auditor, including a balance sheet showing the assets and liabilities of the Institution on October 31, 1924, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

Four vacancies exist in the membership of the Board of Trustees, caused by the resignation of Mr. Dodge, which was regretfully accepted by the Board at its meeting of December 14, 1923; by the death of the former President of the Institution, Robert S. Woodward, on June 29, 1924; by the death of Charles L. Hutchinson on October 7, 1924; and by the death on November 9, 1924, of Senator Henry Cabot Lodge. Nominations for such vacancies have been requested in accordance with provisions of the By-Laws and will be submitted to the Board of Trustees at its annual meeting on December 12, 1924.

The tenure of office of the following officers of the Board of Trustees will expire at the annual meeting on December 12: Mr. Root, Chairman of the Board; Mr. Walcott, Vice-Chairman of the Board; Mr. Forbes, Secretary of the Board; Messrs. Parsons, Paton, and Pritchett as members of the Executive Committee; Messrs. Parsons, Pritchett, and Wickersham as members of the

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Finance Committee; and Messrs. Brookings and Wickersham as members of the Auditing Committee. A vacancy also exists in the membership of the Auditing Committee by reason of the death of Mr. Hutchinson.

ELIHU ROOT, *Chairman*.

JOHN J. CARTY.

W. CAMERON FORBES.

JOHN C. MERRIAM.

WM. BARCLAY PARSONS.

STEWART PATON.

HENRY S. PRITCHETT.

HENRY WHITE.

November 14, 1924

REPORT OF THE EXECUTIVE COMMITTEE.

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1924.

RECEIPTS.		DISBURSEMENTS.	
<i>Interest:</i>		<i>Investment:</i>	
Endowment.....	\$20,179,871.63	Securities.....	\$7,284,253.72
Reserve Fund (Cr. to R. F.).....	631,661.31	Collection charges.....	9,008.82
Reserve Fund (Cr. to Income).....	567,382.82	Administration building and site..	309,915.69
Insurance Fund.....	130,688.96		
Colburn Fund (Cr. to C. F.).....	26,822.14	<i>Pension Fund.</i>	\$7,603,178.23
Colburn Fund (Cr. to Income).....	14,812.88	<i>Insurance.</i>	160,986.68
Pension Fund.....	34,133.13	<i>Grants:</i>	27,325.29
		Large.....	13,410,588.23
		Minor.....	2,628,159.93
<i>Colburn Fund.</i>	52,015.74		16,038,748.16
<i>Sales of Publications:</i>		<i>Publication.</i>	61,208,117.92
Index Medicus.....	96,115.24	<i>General Contingent Fund.</i>	5,102.62
Year Book.....	1,278.61	<i>National Research Council.</i>	150,000.00
Miscellaneous.....	128,790.38	<i>Administration.</i>	
		Trustees.....	661,430.35
<i>Reverments:</i>		Executive Committee.....	41,211.77
Grants.....	205,005.74	Advisory Committees:	
Administration.....	12,021.29	Honoraria 1902-'07.....	11,860.00
Unappropriated Fund.....	23,734.08	Travel and subsistence.....	4,367.41
Gen. Contingent Fund.....	5.25	Salaries.....	678,927.72
		Shipping publications.....	656,567.24
		Rent, surety, telephone.....	62,326.64
		Printing.....	667,669.87
<i>Miscellaneous:</i>		Office expenses.....	40,076.53
Carnegie Corporation of N. Y.		Equipment.....	18,800.14
C. I. of W.....	\$750,000	Building and grounds, supplies,	
National Research C... ..	150,000	janitor, fuel, light, water.....	58,165.52
Special.....	95,000	Contingent.....	1,897.01
		Lectures and exhibits.....	1,940.86
Insurance Fund.....	995,000.00	Organization expenses (1902).....	6,991.98
Pension Fund.....	6,861.51		1,112,233.04
Sale of paper.....	16,032.69		26,305,691.94
	6,495.09		
<i>Redemption and Sale of Bonds.</i>		<i>Cash in Banks.</i>	325,997.55
			26,631,689.49

a Including interest from Income and Building Fund bonds.

b Year Books and Shipping Publications carried under Administration to January 1, 1921, and thereafter under Publication.

c Travel and subsistence in connection with official meetings.

d Including Year Books published prior to January, 1921.

REPORT OF AUDITORS

WASHINGTON, D. C., *November 21, 1924.*

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRs: We have audited the books and records of the Carnegie Institution of Washington for the year ended October 31, 1924. We did not audit the books of the various departments as this is done by the Bursar and Assistant Bursar.

The income from investments and other sources has been duly accounted for and disbursements were supported by proper vouchers.

We counted the cash on hand, and the cash in banks was verified with certificates from the depositaries.

The securities representing the investments were examined by us.

We certify that the balance sheet, the schedules of securities and real estate and equipment, and the statement of receipts and disbursements as shown in the regular printed financial statement of the Institution at the close of business October 31, 1924, are in accordance with the books.

Respectfully submitted,

F. W. LAFRENTZ & Co.,
Public Accountants,
(Formerly The American Audit Co.)

Copies of the Financial Statement, certified by
the auditor in the above report, follow on pages
39 to 43.

REPORT OF AUDITORS.

ASSETS.

Investments (interest-bearing securities):

Endowment.....	\$22,115,189.25
Colburn Fund.....	110,980.00
Reserve Fund.....	3,126,376.13
Insurance Fund.....	397,392.03
Pension Fund.....	158,566.92
Harriman Fund.....	300,000.00
	<hr/>
	26,208,504.33

Cash—

Endowment, Colburn and Reserve Funds, awaiting investment	\$9,446.21
Insurance Fund, for current purposes....	21,121.48
Pension Fund, for current purposes.....	13,754.47
	<hr/>
	44,322.16

\$26,252,826.49

Property Account:

Real Estate and Equipment at original cost—	
Division of Administration.....	340,726.81
Departments of Research.....	3,026,767.77
	<hr/>

3,367,494.58

Current Assets:

Cash—	
In banks.....	281,675.39
Petty cash and stamps	400.00
	<hr/>

Income estimated for the year 1924—	282,075.39
Balance uncollected.....	149,460.18
	<hr/>

Publications and paper—	431,535.57
-------------------------	------------

Books on hand at sale price.....	298,087.80
Printing paper in stock for future publications.....	13,747.41
	<hr/>

311,835.21

Outstanding accounts—

Sundry bills for publications sold.....	3,038.34
	<hr/>

314,873.55

746,409.12

30,366,730.19

LIABILITIES.

Endowment and Other Funds:

Endowment.....	\$22,115,284.06
Colburn Fund.....	111,666.88
Reserve Fund.....	3,135,040.65
Insurance Fund.....	418,513.51
Pension Fund.....	172,321.39
Harriman Fund.....	483,671.75
	<hr/>

\$26,436,498.24

Income Invested in Property..... 3,183,822.83

29,620,321.07

Current Liabilities:

Large Grants.....	\$186,066.91
Minor Grants.....	103,127.31
Publications.....	63,380.78
Administration.....	17,436.84
	<hr/>

General Contingent Fund.....	370,011.84
Unappropriated Balance.....	8,802.48
	<hr/>

431,535.57

314,873.55

Value of publications, paper and invoices.....

30,366,730.19

Receipts and Disbursements for Year Ending October 31, 1924.

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REPORT OF AUDITORS.

Schedule of Securities.

SECURITIES.	Par Value.	Market Value Oct. 31, 1924.	Cost or Value at date acquired
<i>Endowment.</i>			
U. S. Steel reg. 5s 1951, Series A, B, C, D, E, F	\$21,200,000	\$22,260,000.00	\$21,200,000.00
Am. Smelt. and Ref. Co. 1st 5s 1947.....	25,000	24,062.50	22,787.50
Cedar Rapids Mfg. and P. Co. 1st sink. 5s 1953.	25,000	24,625.00	24,253.60
C. M. & Pug. Sd. 4s 1949.....	175,000	89,250.00	159,268.00
C. M. & St. P. gen. 4½s 1989	14,000	11,340.00	13,953.75
Chi. U. Station 1st 6½s 1963	25,000	29,250.00	28,656.25
Cleveland U. Terminal 1st sink. 5½s 1972.....	25,000	26,500.00	25,843.75
Commonwealth Edison Co. 1st 5s 1943.....	16,000	16,080.00	15,695.00
Dom. of Canada 5s 1952.....	50,000	51,500.00	49,500.00
Lehigh and L. E. 4½s 1957.....	325,000	292,500.00	331,568.30
N. Y. Gas & E. L. H. & P. Co. purch. money 4s 1949.....	8,000	6,880.00	6,559.50
Province of Ontario 5½s 1937.....	25,000	26,250.00	25,503.60
South and No. Ala. con. 5s 1936.....	150,000	154,500.00	160,875.00
So. Ry. Co. 1st con. 5s 1994.....	25,000	25,250.00	23,937.50
Standard Oil of N. Y. deb. 6½s 1933.....	25,000	26,906.25	26,787.50
			<u>22,115,189.25</u>
<i>Colburn Fund.</i>			
C. M. and St. P. gen. 4½s 1989.....	4,000	3,240.00	4,070.00
Cleveland U. Terminal Co. 1st sink. 5½s 1972.	10,000	10,600.00	10,300.00
Liggett & Myers Tob. Co. 7s 1944.....	10,000	11,787.50	11,600.00
P. Lorillard Co. 7s 1944.....	10,000	11,787.50	11,497.50
Ore. Short Line con. 5s 1946.....	4,000	4,220.00	3,910.00
Ore. Wash. Ry. and N. Co. 1st ref. 4s 1961....	10,000	8,325.00	7,940.00
Park & Tilford Co. sink. deb. 6s 1936.....	8,000	8,800.00	6,400.00
Penna. R. R. Co. gen. 4½s 1965.....	50,000	46,312.50	51,062.50
Pitts. Shawmut and Nor. 4s 1952.....	42,000	4,200.00	4,200.00
			<u>110,980.00</u>
<i>Harriman Fund.</i>			
So. Pac. S. F. Ter. 4s 1950.....	100,000	85,250.00	100,000.00
C. B. and Q., Ill. Div. 4s 1949.....	200,000	179,500.00	200,000.00
			<u>300,000.00</u>
<i>Insurance Fund.</i>			
Am. Smelt. and Ref. Co. 1st 5s 1947.....	10,000	9,625.00	9,002.50
Am. Tel. & Tel. Co. sink. deb. 5½s 1943	53,000	54,590.00	53,598.25
A. T. and S. Fe gen. 4s 1995	50,000	45,125.00	50,056.25
C. B. and Q. gen. 4s 1958.....	30,000	27,000.00	28,237.50
C. M. and St. P. gen. 4½s 1989.....	1,000	810.00	995.00
Consumers Power Co. 1st ref. 5s 1936.....	25,000	22,687.50	23,812.50
Dom. of Canada 5s 1952	25,000	25,750.00	24,727.50
Great Nor. 1st ref. 4½s 1961	21,000	19,162.50	20,944.00
Ill. Central ref. 4s 1955.....	21,000	18,217.50	19,008.75
Missouri, Kansas and Texas 1st 4s 1990	25,000	20,500.00	19,366.67
New England Tel. & Tel. 5s 1952	12,000	12,120.00	11,934.25
Nor. Pac. ref. and imp. 6s 2047	5,000	5,368.75	5,431.25
Ore. Wash. Ry. and N. Co. 1st ref. 4s 1961 ...	25,000	20,812.50	19,881.25
Ore. Short Line con. 5s 1946.....	25,000	26,902.50	24,468.25
Penna. R. R. con. 4½s 1960.....	24,000	23,760.00	25,095.01
Standard Oil Co. of N. Y. deb. 6½s 1933	5,000	5,381.25	5,311.25
So. Ry. Co. 1st con. 5s 1994	25,000	25,250.00	23,843.75
City of Toronto con. deb. 5s 1949	25,000	24,875.00	24,038.10
Wis. Central Ry. Co. 1st gen. 4s 1949	10,000	8,300.00	7,640.00
			<u>397,392.03</u>
<i>Carried forward</i>	22,978,000	23,835,153.75	<u>22,923,561.28</u>

CARNEGIE INSTITUTION OF WASHINGTON.

Schedule of Securities—Continued.

SECURITIES	Par Value.	Market Value Oct. 31, 1924	Cost or value at date acquired.
<i>Brought forward</i>	\$22,978,000	\$23,835,153.75	\$22,923,561.28
<i>Reserve Fund.</i>			
Am. Smelt. and Ref. Co. 1st 5s 1947.....	15,000	14,437.50	13,510.00
Am. Tel. & Tel. Co. sink. deb. 5½s, 1943.....	47,000	48,410.00	47,354.25
Am. Tel. & Tel. Co., col. 4s 1929.....	50,000	48,750.00	45,500.00
B. & O. R. R. Co. gen. and ref. 5s 1995.....	100,000	85,500.00	102,375.00
Canada So. Ry. Co. con. 5s 1962.....	40,000	40,800.00	39,231.50
Cedar Rapids Mfg. and P. Co. 1st sink. 5s 1953..	25,000	24,625.00	24,025.00
Central Pacific 1st ref. 4s 1949.....	50,000	43,875.00	48,250.00
C. B. and Q. gen. 4s 1958.....	150,000	135,000.00	141,263.75
C. M. and St. P. gen. 4½s 1989.....	15,000	12,150.00	14,925.00
Chi. and N. W. gen. 3½s 1987.....	120,000	90,000.00	100,300.00
Chi. U. Station 6½s 1963.....	75,000	87,750.00	85,610.25
Cleveland U. Terminal Co. 1st sink. 5½s 1972..	5,000	5,300.00	5,153.75
Commonwealth Edison Co. 5s 1943.....	36,000	36,180.00	35,345.25
Consumers Pow. Co. 1st ref. 5s 1936.....	25,000	22,687.50	23,878.50
Dominion of Canada 5s 1952.....	100,000	103,000.00	98,936.25
General Electric deb. 5s 1952.....	155,000	162,750.00	158,213.47
Great Nor. 1st ref. 4½s 1961.....	48,000	43,800.00	48,109.25
Illinois Central R. R. Co. ref. 4s 1955.....	100,000	86,750.00	89,668.75
Int. Rap. Trans. ref. 5s 1966.....	280,000	186,550.00	276,701.00
Kansas City Terminal Ry. Co. 1st 4s 1960.....	50,000	42,562.50	40,520.00
Lake Shore and M. S. 4s 1928.....	50,000	49,250.00	47,000.00
Liggett and Myers 7s 1944.....	98,000	115,517.50	116,083.27
Long Island ref. 4s 1949.....	50,000	41,250.00	48,285.00
P. Lorillard Co. 7s 1944.....	95,000	111,981.25	111,253.50
Missouri, Kansas & Texas 1st 4s 1990.....	50,000	41,000.00	38,661.67
City of Montreal 5s 1956.....	25,000	25,125.00	24,062.50
City of Montreal Sinking 5s 1954.....	75,000	75,375.00	72,375.00
New England Tel. & Tel. 5s 1952.....	30,000	30,300.00	29,858.75
N. Y. Edison 1st & Ref. 6½s 1941.....	50,000	57,000.00	55,573.75
N. Y. W. and Boston 1st 4½s 1946.....	50,000	27,937.50	49,187.50
N. Y. Gas & E. L. H. & P. Co. purch. money 4s 1949.....	18,000	15,480.00	14,927.00
Nor. Pac. ref. and imp. 6s 2047.....	95,000	101,906.25	96,756.25
Nor. Pac. gen. lien 3s 2047.....	50,000	30,500.00	33,101.25
Province of Ontario deb. 5½s 1937.....	35,000	36,750.00	35,787.50
Province of Ontario deb. 6s 1943.....	40,000	46,200.00	43,137.50
Ore. Short Line con. 5s 1946.....	2,000	2,110.00	1,955.00
Ore.-Wash. Ry. and N. Co. 1st and ref. 4s 1961..	50,000	41,625.00	46,375.00
Pac. G. & El. Co. gen. and ref. 5s 1942.....	50,000	47,250.00	46,399.28
Penna. R. R. Co. gen. 4½s 1965.....	30,000	27,787.50	29,837.50
Penna. R. R. Co. con. 4½s 1960.....	101,000	99,990.00	105,608.12
Southern Bell Tel. & Tel. 1st 5s sink. fund 1941.	50,000	48,500.00	47,687.50
Southern Cal. Tel. Co. 1st and ref. sink. fund 5s 1947.....	50,000	47,875.00	46,000.00
Southern Pacific 1st ref. 4s 1955.....	100,000	90,000.00	92,148.75
So. Rwy. Co. 1st con. 5s 1994.....	50,000	50,500.00	47,875.00
Standard Oil of N. Y. deb. 6½s 1933.....	70,000	75,337.50	74,504.75
City of Toronto con. deb. 5s 1949.....	75,000	74,625.00	72,114.32
Union Pac. 1st ref. 4s 2008.....	140,000	121,100.00	128,722.50
City of Winnipeg interim deb. 5s. 1943.....	50,000	49,750.00	48,250.00
City of Winnipeg deb. 6s 1946.....	50,000	55,000.00	53,500.00
Wis. Central Ry. Co. 1st gen. 4s 1949.....	40,000	33,200.00	30,477.00
			<u>3,126,376.13</u>
<i>Pension Fund.</i>			
Am. Tel. & Tel. Co. sink. deb. 5½s 1943.....	25,000	25,750.00	24,943.75
Canada So. Ry. Co. con. guaranteed 5s 1962...	10,000	10,200.00	9,790.00
Cleveland U. Terminal Co. 1st sink. 5½s 1972..	10,000	10,600.00	10,315.00
Dominion of Canada 5s 1952.....	25,000	25,750.00	24,727.50
Liggett & Myers 7s 1944.....	2,000	2,357.50	2,375.50
P. Lorillard Co. 7s 1944.....	5,000	5,893.75	5,863.75
Missouri, Kansas & Texas 1st 4s 1990.....	25,000	20,500.00	19,396.67
New England Tel. & Tel. 5s 1952.....	10,000	10,100.00	9,955.00
N. Y. Gas & E. L. H. & P. Co. purch. money 4s 1949.....	24,000	20,640.00	19,693.50
Oregon Short Line con. 1st 5s 1946.....	20,000	21,100.00	19,550.00
Ore.-Wash. Ry. and N. Co. 1st ref. 4s 1961....	15,000	12,487.50	11,956.25
	26,354,000	26,991,632.50	<u>158,566.92</u>
Grand total			<u>26,208,504.33</u>

REPORT OF AUDITORS.

Real Estate and Equipment, Original Cost.

<i>Administration (October 31, 1924):</i>		
Building, site, and equipment.....		\$340,726.81
<i>Laboratory for Plant Physiology (September 30, 1924):</i>		
Buildings and grounds.....	\$54,705.41	
Laboratory and library.....	28,058.18	
Operating appliances.....	10,951.39	
		93,714.98
<i>Ecological Research (June 30, 1924):</i>		
Building, Laboratory.....	7,054.88	
Library, Operating.....	3,301.58	
		10,356.46
<i>Department of Embryology (September 30, 1924):</i>		
Library.....	1,297.27	
Laboratory.....	7,540.92	
Administration.....	3,899.93	
		12,738.12
<i>Department of Genetics (September 30, 1924):</i>		
Buildings, grounds, field.....	270,005.59	
Operating.....	19,982.42	
Laboratory apparatus.....	12,523.09	
Library.....	23,574.18	
Archives.....	45,488.90	
		371,574.18
<i>Geophysical Laboratory (September 30, 1924):</i>		
Building, library, operating appliances.....	193,068.47	
Laboratory apparatus.....	97,939.31	
Shop equipment.....	11,788.98	
		302,796.76
<i>Department of Historical Research (September 30, 1924):</i>		
Office.....	3,288.52	
Library.....	4,752.73	
		8,041.25
<i>Department of Marine Biology (September 30, 1922):</i>		
Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		52,383.84
<i>Department of Meridian Astrometry (September 30, 1924):</i>		
Apparatus and instruments.....	3,257.34	
Operating.....	3,560.60	
		6,817.94
<i>Nutrition Laboratory (September 30, 1924):</i>		
Building, office, and shop.....	123,772.73	
Laboratory apparatus.....	26,419.09	
		150,191.82
<i>Mount Wilson Observatory (August 31, 1924):</i>		
Buildings, grounds, road, and telephone line.....	197,493.90	
Shop equipment.....	40,842.10	
Instruments.....	513,220.97	
Furniture and operating appliances.....	166,733.07	
Hooker 100-inch reflector.....	599,679.43	
		1,517,969.47
<i>Department of Terrestrial Magnetism (September 30, 1924):</i>		
Building, site, and office.....	207,228.50	
Vessel and survey equipment.....	178,959.52	
Instruments, laboratory, and shop equipment.....	113,994.93	
		500,182.95
		3,367,494.58

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year ending June 30, 1924, including those not only recently authorized, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF EMBRYOLOGY.¹

GEORGE L. STREETER, DIRECTOR.

VASCULAR SYSTEM.

A group of circumstances during the past year has resulted in a broad step in advance in our knowledge concerning the initiation and conduction of the contractile impulses in the embryonic heart. These observations came about, as fortunately happens now and then, through the association of several workers who, through mutual stimulation, contributed different techniques and manners of approach to a common end. Dr. Sabin, after several years' study of the living blastoderms of the chick, had become familiar with the earliest evidences of circulation of the blood and had reached the conclusion that the first contractile waves originate at the sinus end of the heart. Both Dr. Lewis and Mrs. Lewis had been studying the earliest evidences of contraction in bits of embryonic heart-tissue, as seen in tissue cultures, accounts of which have been given in my previous reports. Mr. P. N. Johnstone came into our group from Dr. Elliot R. Clark's laboratory, where he had learned a technique for tying ligatures around the heart-tube in chick embryos as early as the second day of incubation and had found that these ligatures produced heart block. Dr. C. L. Davis had been engaged in a morphological study of the embryonic heart, using serial sections and models of the human heart and controlling his work by observations on the living heart of chick embryos. Out of this group of interests there have materialized results that are of fundamental importance both to the clinician and to the physiologist, some of which have now been published; these I will outline in the following paragraphs.

PRODUCTION OF HEART BLOCK IN THE EMBRYO.

It was found by Mr. Johnstone that delicate ligatures could be placed at different levels around the beating hearts of chick embryos and that he could thus functionally isolate different parts of the heart-tube, producing what is known in the adult as *heart block*, a condition where the subdivisions of the heart beat independently of each other, the coordination normally existing between ventricle and atrium being lost. Since this could be done in embryos of 2, 3, and 4 days' incubation, it became possible for Mr. Johnstone to study contraction of embryonic heart-muscle before the problem is complicated by the ingrowth of nerve-fibers, and where the only conducting system is the muscle itself. Further than that, by altering the level of the ligatures, the different parts of the heart-tube could be observed, both separate and connected, and thus the effect of one part on another could be determined for different stages of growth.

Mr. Johnstone found that when a ligature is tied at the atrio-ventricular junction, the atrium continues to pulsate, while the ventricle and bulbus, after stopping for a moment, begin again to contract, but at a slower rate and more irregularly than that portion of the heart on the other side of the ligature—that is, a definite heart block is produced. If, after the ventriculo-bulbar segment has resumed its contracting, another ligature is placed around the heart at the junction of the ventricle and the bulbus arteriosus, the latter

¹ Address: Wolfe and Madison Streets, Baltimore, Maryland.

stops contracting while the ventricle continues without apparent change. The bulbus in these experiments sometimes fails to beat again, but if pulsation is re-established it is after a longer interval and at a slower rate than in the isolated ventricle.

At present there is some uncertainty as to the exact location of the junction of the sinus venosus with the atrium in these early stages, and this is one of the problems that now face us. Mr. Johnstone placed a ligature in this general region and all that part of the heart-tube cranial to the ligature (atrium, ventricle, and bulbus), after a brief cessation, resumed pulsations, maintaining the regular sequence of atrium, ventricle, and bulbus, though at a slower rate of contraction than before the tying of the ligature. It would thus appear that the ultimate and regulative control of the heart beat must be in the sinus region.

Further experiments were done in which the ligatures, after being firmly tied, were removed, leaving a crushed line of constriction in the cardiac tube that physiologically isolated the portions on either side of the constriction, producing heart block in accordance with the level at which the crushing occurred.

INFLUENCE OF TEMPERATURE ON RHYTHM OF EMBRYONIC HEART.

Dr. Lewis has studied the initiation and character of the early rhythmic contractions of the heart by removing this organ from 2- and 3-day chick embryos and observing its behavior in Locke solution, where it maintains fairly regular automatic pulsations for several hours at room temperature (26°C.), varying in different hearts from 40 to 80 per minute, which is about one-third of that in the freshly opened egg. If the temperature is gradually increased the rate increases: going from 26° to 30° , about 4 beats per minute, from 30° to 35° from 4 to 8 beats per minute, and from 35° to 40° from 4 to 20 beats per minute. The rate of the isolated heart varies definitely according to certain environmental conditions, such as temperature, carbon-dioxide tension, hydrogen-ion concentration, and salt-content of medium, and also upon mechanical stimulation.

In studying the effect of changes in temperature on contraction phenomena of these isolated hearts, Dr. Lewis found that the heart block which Mr. Johnstone had effected by ligatures could be brought about simply by an abrupt rise in temperature. For example, when a heart beating regularly at 92 per minute at 27°C. was placed in a warm box at 38°C. , after 3 minutes the atrium was beating at 120 and the ventriculo-bulbar part at 12 per minute; and when returned to room temperature, within 10 minutes the whole heart was found beating synchronously again at 92 per minute. There was some variation in the behavior of the individual specimens as to the degrees of temperature necessary and the amount and character of the disharmony, but in general the effect was as striking as the illustration given. With few exceptions the atrial end was most resistant and beat most rapidly and the ventricular and bulbar portions, in that order, exhibited a much slower rhythm and showed more tendency to be intermittent. The heart block of the clinicians has been supposed to be due to injury to the atrio-ventricular conduction bundle. Since these young embryonic hearts contain no such bundle, it can not be the explanation here. Nor is it due to any serious injury of the atrio-ventricular or ventriculo-bulbar junctions, since the condition disappears when the hearts are brought back to room temperature. The explanation must rest in the physiological differences existing between

the muscle-cells of the atrium, the ventricle, and the bulbus. Apparently these physiological differences are increased through the circumstances of the experiment and the different parts of the heart are rendered more sensitive to thermal and other changes. It is certainly not temperature alone that causes heart block, because the same temperature in the egg, with the heart in the normal environment, yields a synchronously beating heart.

The inherent difference in the constituent cells of the atrial, ventricular, and bulbar portions of the cardiac muscle-sheet is best shown by dividing the isolated heart into these three parts and studying them in Locke solution. Dr. Lewis made records of such preparations, lying side by side, under various conditions of temperature and in open and closed chambers. This latter point makes a difference, for when the observing chamber is closed with a cover-glass the rate is accelerated, due presumably to the increased CO₂ tension. It is hoped that this important point can be definitely determined. When kept at room temperature it was found, in confirmation of Mr. Johnstone's ligature experiments, that the atrium always beats faster than the ventricle and the ventricle faster than the bulbus. The rate of the atrium approaches closely that of the entire heart. The rate of the ventricle, on the other hand, is usually less than half that of the atrium for the 2-day hearts, and considerably less than that for the 3-day hearts. The ventricular rhythms are more apt to be irregular than the atrial. The pulsations of the bulbus often fail entirely and are usually few in number and irregular when they do occur. All of these things make it quite evident that the relatively fast rate of the ventricle and bulbus in the intact heart is dependent upon stimulus from the atrium. When these parts are separated they show less spontaneity in older stages than younger ones. In other words, the muscle-cells of the ventricle and bulbus tend to lose their spontaneous rhythmicity with age.

CARDIAC JELLY OF THE CHICK EMBRYO.

In the course of his studies on the development of the human heart, which Professor C. L. Davis has been conducting during the past two years, there has been some difficulty in determining the nature of the myo-endocardial space. This is due partly to the scarcity of well-preserved embryos sufficiently young, and partly to the difficulty of distinguishing to what extent artifact enters into the characteristic picture which this space presents. By resorting to the living heart of chick embryos (24 to 72 hours), he has been able to demonstrate that between the myocardium and endocardium there is a substance which does not escape on section of the heart, which is closely adherent to both myocardium and endocardium, and which is elastic and possesses an appreciable density. This substance he finds to consist of a homogeneous transparent jelly, and it is due to its presence that a considerable interval is preserved between the endothelium and myocardial sheet. Whether this jelly serves a functional purpose or is simply a part of the histogenetic mechanism remains to be determined.

IMPULSE PATHWAYS BETWEEN DIVISIONS OF ALLIGATOR HEART.

The Crocodilia being phylogenetically the lowest group of vertebrates possessing a complete interventricular septum, it becomes of interest to determine carefully the nature of the auriculo-ventricular connection in this form as a transitional stage between the simple funnel of the lower reptiles and the reduced bundle of mammals. Dr. F. H. Swett, in conjunction with Dr. Henry Laurens of the Osborn Zoological Laboratory, undertook a mor-

phological study of this heart with special reference to its innervation and the sino-ventricular, the sino-auricular, and the auriculo-ventricular connections. The results of this study have now appeared in their final form.

STUDIES ON THE DEVELOPMENT OF BLOOD-CELLS.

In the report of this Department for the year 1922, reference was made to the work of Professor F. R. Sabin on the origin and differentiation of blood-cells in the chick, her observations being made on vitally stained preparations from embryos of the first 7 days of incubation. This work prepared the way for subjecting blood and its development to experimental methods of investigation. Since that time Dr. Sabin, together with Dr. R. S. Cunningham and Dr. C. A. Doan, who have cooperated with her on this program, has devoted her entire efforts to experimental studies on the development of blood-cells and allied structures. Several features of the work have been published during the past year and, as this report is being written, a general and analytical summary of these investigations is being prepared for the press. On account of the importance of their observations, I shall reserve further reference to these studies until my next report, in order that they may be completely outlined.

A phylogenetic study of blood-cells and their development in amphibians and reptiles, by Dr. Ernst Huber, in association with Dr. Albert Alder of Zurich, has appeared during the past year. This work was done by Dr. Huber before he became associated with the Johns Hopkins Medical School.

LYMPHOCYTES IN CIRCULATING BLOOD.

It was found by Dr. F. C. Lee that ligation of the thoracic duct shuts off the normal avenue into the blood of about 58 per cent of the small lymphocytes, leaving 42 per cent to be supplied by that portion of the lymph system not obstructed by the thoracic-duct ligation. In a series of such animals, Dr. Lee has shown that the increase in the number of small lymphocytes in the circulating blood following intraperitoneal administration of pilocarpin nitrate is the same as for control animals, and therefore one can not regard the spleen as the main source for the lymphocytic increase. The lymphocytosis appears to be mechanically produced through the contraction of the plain muscle of the various organs, causing a discharge of lymphocytes from their seats of formation, first into the lymph vessels and secondarily into the blood-stream.

LYMPH PRESSURE.

Some observations have been made by Dr. F. C. Lee on the pressure changes in the thoracic duct, leading to a better understanding of the forces that drive the lymph through its channels. By means of the improved technique devised by him, Dr. Lee has been able to show that respiration is the most powerful of the forces contributing to the pressure within the thoracic duct.

DEMONSTRATION OF BLOOD-VESSELS WITH X-RAY.

Dr. E. C. Hill, following many experiments, has secured an opaque X-ray injection mass with which it is possible to obtain remarkably clear negatives showing in great completeness the finest arteries and arterioles in fetal and adult animals. The technique perfected by him promises to be of very great value in the study of blood-vessel patterns.

FATE OF CARBON PARTICLES INJECTED INTO THE BLOOD.

It has been definitely established that living or dead bacteria, fine emulsions, and inorganic suspensions, when injected into the blood-stream, are quickly

removed from the circulation through the agency of definite organs, and that the endothelial and reticular cells in these organs, through phagocytosis, play a predominant rôle in the final storage and transfer of the deposited material. In order to study this phenomenon quantitatively and with a substance with which observations may be readily made with the naked eye and with the microscope, Dr. G. B. Wislocki has carried out a series of experiments, using filtered india ink, with carbon particles varying from 1 to 3 microns in diameter and definitely timing the duration of the injection. He was thus able to demonstrate that in rabbits the particles leave the circulation in a very few minutes and are deposited in the liver, spleen, lungs, and bone-marrow. In cats, carbon is similarly deposited in the liver, spleen, and lungs, but not in the bone-marrow. Dr. Wislocki was able also to show that when carbon is deposited in the capillaries of the lung it is gradually eliminated by way of the circulation, the respiratory tract, and the lymph channels, and in this process phagocytic cells (principally clasmatoocytes) play a prominent part. He has made it clear that deposition of carbon in the lungs is not the result of simple filtration.

I may add here that the experiments in the production of adrenal insufficiency, undertaken by Dr. Wislocki in conjunction with Dr. S. J. Crowe, have been published in their completed form. Reference was made to this work in the Year Book for 1922. Their final results show that a fragment of cortex, amounting to about one-fifth of the total mass, is necessary for the maintenance of life. The medulla of the adrenals and the abdominal chromaffin body can be destroyed without producing symptoms.

NERVOUS SYSTEM.

Owing to the importance of determining the early primitive nervous reactions in the fetus and newborn as a foundation for all studies on the behavior in mature animals, a program of investigation in this field has been inaugurated by Dr. L. H. Weed and is being carried out with the aid of his associates as opportunity offers. A study on decerebrate rigidity in the newborn cat and rabbit has been completed by Dr. Langworthy and is now in course of publication. The same investigator is studying the earliest occurrence of motor representation in cortex for movements of the extremities. As rapidly as possible this will be applied to the human fetus.

INNERVATION OF THE TONGUE.

By combining histological studies with physiological experiment, Dr. Langworthy has contributed to our knowledge of the innervation of the musculature of the tongue. Working with the cat, fetal pig, opossum, and rat, he has been able to show that when both hypoglossal nerves are cut and allowed to degenerate, complete paralysis of the tongue ensues, and that neuro-muscular spindles that had previously been present disappear. On the other hand, bilateral section of the lingual and glosso-pharyngeal nerves causes no apparent ataxia and the neuromuscular spindles do not subsequently disappear. We must therefore assume that the hypoglossal nerve carries the proprioceptive fibers from the extrinsic muscles of this organ. Dr. Langworthy has also demonstrated that section of the hypoglossal nerve is followed by degeneration of the cells of the hypoglossal ganglion, the so-called Froriep ganglion, and of the small group of sympathetic motor-cells that lie ventral to the hypoglossal nucleus, thereby proving that fibers from these cells run in the hypoglossal nerve.

THE CHOROID PLEXUS.

Another step has been added by Professor Weed to his logically progressing study of the effects upon the nervous system of intravenous injections of saline solutions of various concentrations. He has found that in dogs, subjected to intravenous injections of hypotonic solutions, the consequent increase in the pressure of the brain is associated with definite morphological changes in the choroid epithelium and dilatation of the perivascular and perineuronal spaces of the central nervous system. The changes in the choroid epithelium are in the nature of an increased volume of the cells with the formation of a clear vacuolar zone in the distal portion of the cell, and are quite similar to, though more extensive than, those produced by pilocarpin, muscarin, or ether. The degree of these morphological changes corresponds to the degree of the pressure change in the cerebrospinal fluid and they are apparently the morphological expression of the passage of water into the cerebrospinal fluid and into the nervous tissues. These experiments must therefore be regarded as substantiating the hypothesis that the choroid plexuses elaborate the major portion of the cerebrospinal fluid.

A NEW INTRAVENTRICULAR SOURCE OF CEREBROSPINAL FLUID.

Continuing their observations on the *area postrema*, Dr. Wislocki and Dr. T. J. Putnam have shown, by the intravenous injection in cats of iron ammonium citrate and potassium ferro-cyanide, that the capillary walls in this particular region of the fourth ventricle are more permeable to salts contained in the blood-stream than those of other parts of the central nervous system. It raises the interesting question as to the possibility that these structures constitute a source of cerebrospinal fluid content additional to that secreted by the choroid plexuses. In the embryo it is clear, from Dr. Weed's studies, that the ependyma must produce the cerebrospinal fluid up to the time of the specialization of the choroid plexuses. It seems likely that after their establishment the ependyma loses this power except in regions of the *area postrema*.

THE MENINGES OF BIRDS.

It has been shown by Mr. O. C. Hansen-Pruss that the enveloping membranes of the central nervous system of birds is essentially similar to the three definitive membranes of mammals. He has demonstrated a functional subarachnoid space containing a true cerebrospinal fluid. The avian meninges, however, present one feature that is strikingly different from anything seen in the mammals, that is, a peculiar transformation of the subarachnoid space in the lumbar region of the cord, the *sinus rhomboidalis*. In this isolated area he finds that the subarachnoid mesh is distended with a gelatinous colloid producing a mass that fills the wide interval separating the posterior columns of the cord. Concerning the function of this tissue little is known, although there is recent evidence that it produces glycogen.

PHYSIOLOGY OF REPRODUCTION.

OVULATION AND MENSTRUATION IN *MACACUS RHEBUS*.

An achievement of notable importance is to be credited to Dr. G. W. Corner, who, with a small colony of monkeys (*Macacus rhesus*), has correlated the principal phenomena associated with menstruation of primates with the corresponding phenomena in the better-known oestrous cycle of lower forms. He has demonstrated the first indubitable unfertilized ovum ever seen in any primate after leaving the ovary and has shown that its maturation is not different from that of other mammals.

In Dr. Corner's colony there were 11 female specimens which he kept under daily observation, and under favorable conditions for the maintenance of good health, for periods of one year, and two years and one month respectively. All of them exhibited menstrual phenomena and the records thus obtained by Dr. Corner constitute the first detailed account of the menstrual cycle for this species. The periodicity of menstruation proved to be less regular than that of human mature subjects, but this greater irregularity may have been due to the youth of the animals. The commonest cycle-length was 27 days, and about half of the 132 cycles recorded fell within the limits of 23 to 31 days. No cycle was less than 15 days. The duration of the flow was from 4 to 6 days.

Since the vaginal secretions of rodents exhibit marked changes in the different periods of the œstrous cycle, it became a matter of special interest to detect, if possible, a correlated phenomenon in the monkey. For this purpose smears were made from the vaginal lumen of each monkey daily. From these it was found that, though far less sharply defined than that seen in rodents, there is a recognizable cycle characterized by the disappearance, or diminution in number, of the vaginal leucocytes, usually occurring in the 10 or 15 days preceding the onset of menstruation. Monkeys do not have the conspicuous desquamation of cornified epithelial cells, such as occurs in the rodent cycle. There is, however, some increase of epithelial desquamation during the latter half of the intermenstrual interval along with an increase in the glycogen content of the desquamated cells. With the onset of menstruation the vaginal content becomes invaded with red blood-cells and there is a reappearance of numerous leucocytes. What epithelial cells are present are of vaginal origin and no fragments of the uterine stroma or epithelium were detected.

After the character and periodicity of their menstrual flow were determined, the animals were sacrificed at selected intervals and an examination made of their ovaries, uteri, and accessory organs of reproduction. The prime object was, of course, to correlate menstruation with ovulation and to observe the anatomical changes in the genital organs dated with respect to these two events. First of all, it was found that in more than half (6) of the animals regular menstruation had occurred without a corresponding cyclic maturation of follicles and formation of corpora lutea in the ovaries; that is, in *Macacus rhesus* menstruation may occur without ovulation. From the fact that where this happened the animals had been menstruating (or at least had been under observation) only one year or less, one may suppose that it was due to their youth. In the 5 animals in which ovulation did occur it was found to take place in definite chronological relation to the menstrual cycle, about 12 to 14 days before onset of the menstrual flow. The premenstrual period in the primates would therefore correspond to the postœstrous period of other mammals. The successful experience in the management of a monkey colony that Dr. Corner passes on to us, and the evidence that he has produced regarding the correlation between ovulation and menstruation, prepare the way for securing material from the first two weeks of development, the most obscure period in the development of the primate embryo.

RHYTHMIC CONTRACTIONS OF THE OVIDUCT OF THE MONKEY.

It is well known that strips of the muscular walls of the uterus and oviducts, when suspended in a suitable solution, undergo regular rhythmic contractions like involuntary muscular tissue from other organs. In my last report I

described the observations of Mr. D. L. Seckinger and Mr. J. D. Keye, who found in the sow that the rate and amplitude of the contractions of such strips are subject to periodic variations at successive stages of the oestrous cycle, suggesting the hypothesis that the varying curve of the contractions may represent a muscular mechanism for the transportation of the ova through the tube and uterine canal. When the monkeys of Dr. Corner's colony were killed for anatomical examination, opportunity was taken by Mr. Seckinger and Dr. Corner to make observations on the contractions of the oviducts of eight of them, representing nearly all stages of the menstrual cycle. In one of these, where the ovary showed a recently ruptured follicle and the shed ovum was found in the oviduct, an undulatory contraction wave was obtained, interrupted by more rapid contractions very closely resembling the contraction wave that characterizes the oviduct of the pig during the oestrous period. In all of the others the monkeys had not recently ovulated and the curves corresponded to those obtained from the pig in the interoestrous intervals, with regular contractions three to eight times per minute. Their observations demonstrate the significant fact that, not only in pigs but in fairly high primates (*Macacus rhesus*), there is a special type of contraction of the oviduct during the presence of the ovum within its lumen.

RHYTHMIC CONTRACTIONS OF THE HUMAN OVIDUCT.

After it was found that there is a characteristic type of rhythmic contraction of the tube at the time of ovulation in both the pig and the monkey, Dr. Snyder and Mr. Seckinger undertook the investigation of contractions of the human oviduct. Through the cooperation of the surgeons in charge of the Women's Clinic of the Johns Hopkins Hospital, they obtained more than 40 freshly removed human tubes showing no obvious pathological change. From this material they obtained two types of tubal contractions. In one type the contractions were slow and of uniform amplitude, while in the other they were more rapid and exhibited a tendency to periodic variation in amplitude. Curves were also obtained that were transitions between these two characteristic types. Since the tubes were accompanied in most instances by the uterus and ovaries, it was possible to study the three microscopically in the same individual and to determine the correlation of the striking variation in contraction with coincident histological changes. It was found, as a rule, that the slow contractions of equal amplitude occurred throughout pregnancy and during the premenstrual, menstrual, and early interval stages of the cycle. The more rapid contractions of unequal amplitude were observed during the mid-interval and late interval phases. As we have seen above, it is this latter type of contraction that is characteristic of the time of ovulation in the sow and monkey and we may assume that the phenomenon is common to all mammals.

CYCLIC HISTOLOGICAL CHANGES IN THE HUMAN OVIDUCT.

The histological studies of Dr. F. F. Snyder on the oviduct of the sow, referred to in my last report, have been extended by him to the human oviduct. He succeeded in collecting 75 suitable specimens representing the different stages of the reproductive cycle. The majority of these specimens were obtained from operations in cases of myomata of the uterus. They are all accompanied by reliable clinical histories with records including the age of the patient, the age at onset of menstruation, regularity of occurrence, duration, amount of flow, date of onset of last period and of the preceding one,

occurrence of intermenstrual bleeding, marital history, date of operation, and report of pathologist on the tissues removed. The tubes chosen were without any obvious pathological change and the history indicated no marked functional abnormality of the menstrual cycle from the time of puberty. Of the 75 tubes studied, 62 were from non-pregnant and 13 from pregnant women. As a result of the examination of this material, Dr. Snyder has found that clear-cut periodic changes occur in the structure of the tubal epithelium, involving the height of the epithelium and the morphology of the non-ciliated cells, very much like the changes seen in the oviduct of the sow. Fortunately, it was possible in 31 of the specimens to correlate the structural variations in the tubes with the coincident state of the uterine mucosa. Thus it was determined that of the two chief phases, the one of low epithelium is coincident with the premenstrual phase of the endometrium and occurs throughout pregnancy; the state of high epithelium attains its maximum at the mid-interval phase of the endometrium, presumably at about the time of ovulation. The fact that cilia were found throughout the menstrual cycle and pregnancy, without any change in appearance or variation in number, casts doubt on their interpretation as a factor in the reproductive cycle, and it is not likely that sterility and pathological conditions of implantation can be attributed to alterations in their number or activity, as some pathologists have maintained.

CYTOLOGY.

REVERSIBLE GELATION IN LIVING CELLS.

During the past year Mrs. M. R. Lewis has continued her studies on the chemistry of the living embryonic cell and has found that it is possible to make the cell-protoplasm more solid or more fluid by treatment of the tissues with acids or alkalis respectively and, furthermore, the phenomenon may be reversed by washing off the acid or alkali and the cells continue to live. That gelation and solution of the cell may be thus reversed throws new light upon the complex nature of protoplasm, and Mrs. Lewis has made a further important contribution in showing that in these respects the nuclear substance is different from that of the cytoplasm.

When a culture of embryonic tissue is washed with a saline solution, to which enough of any of the ordinary acids has been added to give it a pH of 4.6, Mrs. Lewis finds that the cells undergo coagulation and take on the appearances that are regarded as characteristic of cell death: the nucleus becomes granular and acquires a bright, thick membrane around it; in the cytoplasm, the mitochondria begin to swell or become round, and all of the granules, particularly the mitochondria, cease their activity; the dividing cells remain in the stage of mitosis, attained before the application of the acid, and acquire coagulated spindle-fibers that are not seen in living cells; and the clasmotocytes stop sending out or retracting pseudopodia. If now, before the coagulation proceeds farther, the acid solution is washed off, the cells recover their normal appearance. The nucleus becomes homogeneous and its shiny membrane disappears; the mitochondria and granules of the cytoplasm begin again to exhibit movement, the cells in mitosis complete their division, and other cells that had not started to divide prior to the application of the acid begin to undergo mitosis. If such a culture is returned to the incubator it may live as long and remain in as good condition as the controls. In other words, the gelation is reversed. If it is surprising that cells thus gelated are capable of recovery, it is still more surprising that the gelation can be brought about

and reversed several times in succession. In such cases, however, the cells do not live as long or remain in as good condition as the controls or the cultures experimented upon only once. Furthermore, the more acid used the fewer times can reversal of the gelation be accomplished and the more rapidly must the acid be washed off.

It was found by Mrs. Lewis that whereas the state of the cell could be made more solid by means of acids, it could also be made more fluid by means of alkalies. The hydrogen-ion concentration of the solution of different alkalies necessary to bring about this phenomenon varied. Usually a solution pH 8.6 to 9 was enough to cause fluidity of the cytoplasm. The fluid state brought about by application of alkalies is indicated by the cells beginning to round up instead of remaining spread out on the coverslip, by the mitochondria changing from long filaments to short rods or granules, and by a slight dancing of all the granules. These changes are followed by the appearance of fluid blebs along the edge of the cell and finally the whole cell becomes a round mass around which the cytoplasm flows as a fluid, bleb-like pseudopodium, the granules of which are in active brownian movement. By bathing the cultures with a normal solution the process can be to some extent reversed, although the cell never spreads out again. As soon as the alkali is removed the blebs disappear, all brownian movement of the granules stops, those cells in mitosis complete division, and cells migrate out from the explant. If the culture is returned to the incubator it lives, though not so long as the controls. By increasing the alkali to pH 10 the nucleus and nucleoli can be dissolved and later brought back by washing off the alkali. In this reversal, however, the nucleus appears slightly clotted instead of homogeneous and the cells do not live.

It will be noted from the above that the gelation and solution of nuclear substance, as compared with that of the cytoplasm, shows distinct differences. The nuclear substance is more readily coagulated by acids; on the other hand, the cytoplasm is more rapidly rendered fluid by an alkali than is the nucleus. The reversal of gelation of the nucleus can be readily accomplished and the cells continue to live, but the reversal of the gelation of the cytoplasm is more difficult and the cells seldom live. On the other hand, when the cytoplasm is made more fluid by means of an alkali it can be reversed to the gelatinous state and to some extent the cells continue to live, but when the nucleus is dissolved by an alkali the cells never recover.

In connection with the study of gelation phenomenon, Mrs. Lewis made similar observations upon embryonic heart-muscle. She found that cross-striated fibrils could be produced by means of the acid and, providing not too much had been used, they could be removed by washing off the acid. Owing to the thickness of the cell-layers, the penetration of the acid is slow and the heart continues to beat for some time but becomes quiet as the fibrils appear. The nuclei, as well as the fibrils, become coagulated and the gelation can be removed by washing out the acid.

I can not leave this subject without referring to the interesting discovery that one of the most effective acids in bringing about the gelation of living cells was that obtained from sterile dead tissue. Gelation produced by this means could be removed by washing off the solution, but when it was not washed off the cells died. This fact should be of clinical importance in explaining the toxic nature of crushed or burned tissue.

INGESTION OF CHLOROPHYL BY TISSUE-CULTURE CELLS.

In previous reports reference has been made to several studies from this laboratory on the mechanism of phagocytosis, in which it has been shown that connective-tissue cells of the chick embryo are able to take in a wide range of foreign bodies. Mrs. M. R. Lewis has recently added a new substance to this list, namely, chlorophyl, and has produced animal cells that are as green as any plant cell. She finds that connective-tissue cells growing in an emulsion of an alcoholic extract of chlorophyl exhibit the same behavior towards the green globules that they do toward other foreign bodies, especially fat globules. There is no purposeful action between them. The contact between the chlorophyl and the cell takes place entirely by chance. The cells make no effort to engulf the globules and no cell processes flow around them. Clasmato-cytes exhibit the greatest amount of ingested chlorophyl, often becoming so full of green globules that the other structures of the cell are obscured. Cultures containing cells that had ingested chlorophyl lived, divided, and degenerated about the same as the controls. Apparently there occurs little or no digestion of the globules and no green color appeared in any of the mitochondria. The chlorophyl seemed to be of no particular benefit nor of any harm to the cells.

EFFECT OF PYROGALLIC ACID UPON LIVING EMBRYONIC CELLS.

It was thought that definite evidence concerning the site of intracellular oxidations and reductions might be obtained by treating tissue-culture cells with pyrogalllic acid because of its well-known property of uniting with uncombined oxygen. This experiment was not successful, owing to the fact that this acid proved to be toxic, producing paralysis of the cell followed by precipitation of the cytoplasm and nucleus. Observations were made, however, by Mr. J. T. Bauer, who carried on these experiments on the changes produced by this acid on vitally stained cells in which there resulted a disappearance of the dye from the mitochondria, granules, and vacuoles, presumably due to a withdrawal of oxygen.

AMNIOTIC ECTODERM.

As part of his program of determining the characteristics of the principal cell-types, as they are seen in tissue cultures, Professor W. H. Lewis has added to those previously published a study of ectoderm cells, his cultures being obtained from amnions of chick embryos. Especial interest is attached to ectodermal tissues, owing to the prominent rôle they play in wound healing. His study covers the manner in which epithelial cells migrate from the explant, the character of epithelial membranes, and the cytological structure of the individual cells, including the variations they show under alterations in their environment. In studying the nature of the attachment of the cells to each other, he found that in considerable part it is accomplished by a demonstrable cement substance. Where this was not present there appeared to be simple adhesion of the cells with no actual fusion of the cytoplasm. There is, therefore, no warrant for regarding epithelium as a syncytium. It is interesting to note that epithelial cells differ from mesenchyme cells in exhibiting no centriole or centrosphere, nor are the mitochondria or cytoplasmic granules grouped about such a center.

MESENCHYME AND MESOTHELIUM.

The work of Dr. Lewis, mentioned in the last Year Book, demonstrating that mesothelium is derived from mesenchyme simply by a change in the form

of its component cells and is not to be regarded as a differentiation in structure, has now been published in its final form. His paper is accompanied by photographs showing the various steps in this process.

STRUCTURAL INTERRELATIONS OF FIBROBLASTS.

Further evidence has been secured by Dr. C. F. DeGaris concerning the interrelations of fibroblasts, in which he supports the view of Dr. Lewis, which is that they are not fused in a common syncytium, but that the cells constitute independent units which are merely in contact. Dr. DeGaris studied the movement of neutral-red granules along cytoplasmic processes that were optically continuous, and could find no exchange of granular material from cell to cell. He also studied fibroblasts during bleb formation, and, though cells might be in apparent continuity, they showed individual reactions to the environment and there was no coalescence of blebs or interflow of cytoplasm, indicating physiological independence.

TISSUE-CULTURES UNDER DARK-FIELD ILLUMINATION.

A successful attempt to make use of dark-field illumination for the study of tissue-cultures has been made by Dr. W. H. Lewis. This technique gives entirely new pictures of cell-structures and, for certain features of cell-motility, has already proved indispensable. Tissue-cultures, with their cells spread out thin and flat against the cover-glass, prove to be well adapted to the use of this method, which, although it will not supplant the bright-field, becomes a valuable supplement. Dr. Lewis has published an account of the cytological appearance of mesenchyme, endothelium, smooth-muscle, heart-muscle, skeletal-muscle, ectoderm, endoderm, liver-cells, clasmatocytes, and sympathetic nerve-fibers, as seen with this method. It is particularly favorable for the study of brownian motion of degeneration granules and mitochondria, which varies according to the consistency of the cytoplasm, whether it is more fluid or semi-solid. Much less brownian motion occurs in smooth muscle and skeletal muscle than in most other tissues, and none at all occurs in heart-muscle. As the cells die, the cytoplasm and nucleus become loaded with fine white granules, which at first may show brownian motion. Motion ceases later in all three types of granules. The degeneration granules and mitochondria finally disappear, but the fine white granules can be seen until the cell disintegrates.

CULTURES OF MOUSE SARCOMA.

Using a saline solution containing embryonic juice, or juice obtained from the uterus or placenta, W. H. Lewis and G. O. Gey have been successful in culturing bits of sarcomatous tumors removed from mice. In studying these growths it became apparent that two types of cells migrate out from the explant, one of which represents the sarcoma cells and the other type these investigators were able to identify as the ordinary clasmatocyte or resting wandering cell. The discovery that clasmatocytes are present in these tumors is of much pathological interest, and it will be of importance to determine their source—whether they come from the host or are produced by multiplication within the tumor.

GROWTH AND REGENERATION.

FETAL GROWTH IN MAN.

In my last report mention was made of the investigations of Dr. A. H. Schultz upon body proportions during the antenatal period, which at that time were practically completed for the extremities and the trunk. Since then the head measurements have been completed and analyzed, which makes it now possible for Dr. Schultz to assemble this important study in its detailed and final form for publication. His investigations are based on the collection of over 5,000 human embryos and fetuses of the Carnegie Collection, of which 623 were selected as most suitable for study; these included both white and negro, ranging in age from the ninth week to term.

FETAL GROWTH IN PRIMATES.

As by-products of his studies on the development of the human fetus, Dr. Schultz has made a series of observations on the growth of other primates and has studied its relation to the growth of man and its significance with reference to man's evolution. He finds many striking resemblances between man, ape, and monkey in early development, and is of the opinion that the frequently closely corresponding growth changes can only be explained by one common origin, from which all have inherited the tendency for the same ontogenetic processes, which are only modified through later specializations. Among these growth resemblances is the reduction in relative head size with advance in growth, which is explained by the general rule according to which the cephalic end of the body shows an initial acceleration as compared with the more caudal portions; this is true also for the trunk and extremities. The considerable change in shape which the chest undergoes in the course of growth is much the same in man, orang-utan, and gibbon. In lower primates (monkeys and lemurs), however, the index decreases with advance in growth. The lower and higher primates are more alike in embryonic and early fetal stages than in adult life, as one would expect with a common ancestry for all primates. The situation of the nipples, which are lower in man than in any of the other primates, appears to be a recent specialization. In man they become lower in postnatal development, while in all apes and monkeys they become higher. The common ancestor must have had nipples situated somewhere between the exceedingly high position in such primates as orang-utan and *Alouatta* and the low position in man. In the measurements of the extremities the other primates show some variations in the nature of recent specializations, but in general their development is in close harmony with that of man.

Carpal vibrissæ are present in many of the mammals. They take the form of sinus hairs, implanted in a distinct hillock of skin on the wrist, and receive a branch of the ulnar nerve. They are interpreted as touch organs. It has been assumed that among the primates these carpal vibrissæ occur only in the platyrrhines, and then only in one of the most primitive forms, where they persist throughout life. Dr. Schultz has now found them to be present in the *Colobus* monkey during a short period of fetal life. He has also noted the presence of the carpal hillock, without the hairs, in a small percentage of human fetuses, where it persists for only a short time. This distribution of the carpal hairs among the primates and the infrequency and early resorption of the hillock in man, constitute a feature of evolutionary significance and prove clearly the atavistic nature of the carpal hillock in man.

The hand and foot, in their developmental stages, are particularly striking examples of the close relationship existing between monkeys, apes, and man. In this respect the primates can hardly be distinguished from one another in early fetal stages. With advance in growth the hand becomes narrower and the thumb shorter in all primates. There is a proximal ontogenetic migration of the thumb from its primary position near the base of the index finger, which is most pronounced in orang, somewhat less in the other anthropoids and man, and still less in the Old World monkeys; while in platyrrhines no such shifting takes place, the thumb persisting in its typically fetal position throughout life. In the foot the relation in length between the first three toes undergoes important changes during development. In all monkeys and apes the middle toe surpasses all the others in length. Occasionally, man also conforms to this rule for a short transitory stage in his ontogeny, since in a fair percentage of fetuses from the end of the second and the beginning of the third month the middle toe is the longest. Very soon afterward the second toe becomes the longest in the large majority of cases; not until the fourth month does the great toe begin to project farther than any of the other toes, and then only in a small minority of cases. The frequency of instances in which the great toe is shorter than the second decreases in both races with advance in fetal development, but such cases always remain more common in the negro than in the white. As far as the hallux alone is concerned, the difference between man and gorilla is no greater than that between the gorilla and orang. In man the great toe has become lengthened and adduced, both phylogenetically and ontogenetically, while in the orang it shows a marked tendency toward far-reaching reduction, the nail, for instance, in most orangs having already become lost and a single phalanx is not a very rare finding. In general, ontogenetic changes in the foot offer strong support for the theory that the feet of all primates originated from one common type, from which man and the monkeys differentiated in opposite directions. The monkeys have deviated more from the original than has man.

The eyes move relatively closer together with advance in growth in all primates. In man, the relative interocular width is as great in early fetal life as in adults of most other groups of animals. Man does not occupy a separate place in this feature of development, but stands at any age well within the range of variation, in the approximation of the eyes, exhibited by his simian relatives. Of these the *Prosimiæ* retain by far the most primitive and therefore the widest interocular space, while many of the monkeys, and the orang particularly, have progressed to a higher specialization in this regard than man. Thus one sees that man in some respects is less specialized and has hence remained, phylogenetically as well as ontogenetically, more original and "primitive" than various other primates.

INFLUENCE OF THE MAGNETIC FIELD UPON GROWTH.

Dr. F. C. Lee, in conjunction with Professor F. W. Lee, of the School of Engineering of the Johns Hopkins University, endeavored to determine whether magnetism has any observable effect upon biological activities. They exposed eggs of rainbow trout and salamander to a constant, uniformly rotating magnetic field continuously for 26 to 45 days. Under these circumstances no difference could be seen in the development of the specimens within the magnetic field from those in control vessels. The magnetic field was obtained by a three-phase winding upon a uniform iron coil 14.25 cm. in

diameter. The coil was operated upon the service of the local power company at a frequency of 62.5 cycles per second. The field tested to a strength of 1,410 gaussess maximum. It seemed possible that such a magnetic field might affect the configuration of the electrons and alter the dynamic equilibrium of the atom, thus secondarily affecting the molecule and thereby causing changes which could possibly be observed in the study of growth. In the absence of such an effect one must infer that, in the case of growth, matter is composed of atoms, the electrons of which are in a state of static equilibrium. Other experiments were carried on with rapidly multiplying organisms. Strains of both large and small bacilli were placed in an incubator in the center of the coil. Here, also, no difference was detected from control specimens, either in growth or morphology.

In studying the process of repair in end-to-end anastomosis of the intestinal tube, Dr. Lee has devised an instrument by which a new surgical procedure is made possible for aseptic anastomosis of the colon. Due to its infectious content and the nature of its anatomical structure, it has been much more difficult to perform an anastomosis on the large intestine than on the small intestine. The simplified technique of Dr. Lee partially obviates these difficulties and is proving of great aid in the continuance of his studies on mucosal and vascular regeneration. Of equal importance is its value in clinical surgery.

MECHANICAL INITIATION OF REGENERATION.

In working with amphibian (*Amblystoma*) larvæ, Dr. F. H. Swett finds that a localized diminution of differentiation potency may occur in the case of limb-forming cells, resulting in the failure of the limb to develop, or, where the rudiment of the limb has been experimentally ablated, the limb may fail to regenerate. In either event the larva exhibits a total unilateral absence of the forelimb. Selecting such specimens, Dr. Swett endeavored to arouse differentiation through mechanical stimulation, scarifying the limb region with needles. The results were negative in all but one case. In that one, however, the growth processes in the limb region were initiated by the stimulation, and in the course of a few weeks an abnormal bidigitate limb was formed, capable of performing limited spontaneous movements.

MINOR SYMMETRY IN DUPLICATE LIMBS.

Reduplication of the limbs or appendages have been frequently observed in insects, crustacea, and amphibians, occurring both in nature and under experimental conditions. It has been found that the extra limbs exhibit rather definite symmetries and mirrored relations with the normal. Dr. F. H. Swett has been studying this problem in connection with the series of limb transplantations that he has been performing on amphibian larvæ, with a view toward an interpretation of the interesting phenomena of regeneration that are here involved. In the matter of right- and left-sidedness and the determination of posture, the problem becomes more complicated than that of the ear vesicle, on which I worked some years ago, as mentioned in previous reports. It becomes more complicated through the factor of regeneration and also because the limb-bud appears to be equipotential, at least in the dorso-ventral axis. Certain rules, however, have become fairly established; for example, in practically every instance in which two or more limbs are produced where one should have formed, the members of the complex obey the rules of minor

symmetry, as formulated by Bateson and Harrison. Dr. Swett has collected 16 instances of abnormal limbs that are exceptions to these rules. In publishing a description of these he offers detailed interpretations based on known developmental factors. The investigation on this important question of the formation of duplicate limbs is being continued by him and a general survey of the problem is now in preparation.

REGENERATION OF NORMAL LIMBS FROM ABNORMAL STUMPS.

The question as to whether an abnormal limb, if amputated, would tend to regenerate a similarly defective limb or not, has been taken up by Dr. Swett who has had the opportunity of testing this point in connection with his studies on the factors involved in reduplication and the mechanism of regeneration, which I mentioned under the preceding heading. He has been able to show that if one amputates an abnormal limb it is not replaced by a similarly abnormal one, but the process of regeneration tends toward the production of a morphologically normal appendage. The stump of an amputated abnormal appendage does not appear to exert any specific influence on the regenerating limb. Even in heterotopic and heteropleural limbs complete normal regeneration is obtained. The amputations were made through the limb at various levels without affecting the result, and it was found that the character of the limb at the level where the cut was made had very little to do with determining the nature of the resultant part. A wound surface through two fused limbs is no more likely to regenerate a double appendage than is a bud derived from a cut through the normal part of an abnormal limb.

In a series of undersized and markedly stunted limbs, it was found that when amputated they were replaced by regenerates that were also deficient and tended to be still smaller than the original. None of them was normal. The failure of any complete regeneration in this group was found to be due in considerable part to insufficient nutrition. It was not due to a repetition in the regenerate limb of the specific deficiency of the original.

PHYLOGENY OF THE PANNICULUS CARNOSUS.

The investigations concerning the phylogeny of the facial musculature in the dog and cat, followed out by Dr. Ernst Huber and referred to in my previous reports, have this year been extended to the other superficial muscles of the same animals by Dr. O. R. Langworthy. He has given his attention particularly to the panniculus carnosus and to the pectoral musculature with which he finds the former is genetically related.

PATHOLOGY OF THE EMBRYO.

It is clear that every fertilized ovum possesses those properties requisite for the production of an end product exhibiting all the peculiarities of its kind. It is also clear that every such ovum must differ from all other ova in its structural and physiological properties to the extent that each mature individual possesses its own peculiarities and characteristics, which we speak of as inherited. I wish to call attention to one of these properties, an indefinite one for which we have no better term at present than the designation *vitality*. Our knowledge concerning this property is meager enough, but it is a factor of great clinical importance and through it we are beginning to understand some phases of the difference between normal and abnormal processes of develop-

ment. What is meant by this term *vitality* is best illustrated in lower forms. In a given cluster of frog's eggs, all having the same histological appearance, there are always some that, even under the ordinary conditions, fail to develop. By the introduction of an unfavorable temperature or other injurious environmental factor, one can experimentally increase the proportion of egg failures to any desired extent, in so far as the eggs differ in the possession of this property of vitality. From Dr. George W. Corner's interesting observations on intrauterine mortality of the pig, where he was able to rule out environmental abnormalities, it appears that to a large extent death and abnormality are due to deficient vitality of the eggs. The difference in their possession of vitality determines the amount of development of which they are capable. About 10 per cent of them never segment, another 10 per cent stop development at the blastocyst stage, and 5 to 10 per cent are arrested or show abnormalities in development during the subsequent course of pregnancy, leaving about 70 per cent that develop into normal mature pigs. There is much evidence indicating that in man (I include, of course, both the maternal and paternal germinal elements) there is a great variation in the amount of vitality possessed by different eggs. In some cases we meet with habitual ovulation of poor eggs, such parents being classed as sterile. In other cases a series of more vigorous eggs may be interrupted by eggs of less vitality, and there thus occur inevitable abortions between normal-born infants. In still other cases all eggs show a high degree of vitality and such parents are known as prolific.

FAMILIAL RETINO-CEREBRAL DEGENERATION.

This deficiency in vitality, which I have defined in the preceding paragraph, may involve the whole egg or only certain of its elements. There thus exists a great variety in the results for which it is accountable. If only certain elements of the egg are deficient, we find a group of abnormalities limited to the structures derived from those elements. Localized anomalies are largely of this character. The embryos may reach maturity and be otherwise strong and normal. An interesting study of a case of this kind has been made by Dr. R. S. Cunningham in conjunction with Dr. W. H. Nardin. They have described the occurrence of retino-cerebral degeneration in a family in which five of the nine children suffered from the condition. The onset occurred at about the seventh year with impaired vision and pigmentation of the macula. This was followed by epilepsy and progressive mental deterioration. Optic atrophy, complete blindness, and imbecility followed, terminating in death. The etiology of this condition has been wholly obscure, though it is certainly not of an infectious nature. Dr. Cunningham suggests that we are dealing with a congenital lowered vitality, not of the whole individual, but of a part, namely, the derivatives of the anterior end of the medullary plate. These tissues were deficient in vitality and did not have sufficient resistance to bear the strain of complete development and the exigencies of their normal activities. The consequent clinical phenomena are those distressing symptoms which result from the premature senescence and breaking down of the tissues involved.

SINGLE-OVUM TWINS.

In closing my report for the last year I referred to the evidence that had accumulated in this laboratory upon the problem of the formation of monochorionic twins—evidence that this type of abnormality is a result of germinal defect and that it may occur in a perfectly normal environment. I referred to a very young specimen of twinning in the pig in the stage of a bilaminar blastocyst, which I have since had an opportunity to study carefully. The specimen is the youngest known case of twinning for this species, and there is only one other correspondingly young and normal specimen known for mammals of a higher order than edentates. This specimen unquestionably gives us a true picture of twinning at this early stage and there are certain definite things that it teaches.

In the first place, it is clear that the twins were developing from a single blastocyst. There has existed some doubt as to whether this ever happens in the pig, the suggestion being made that what appeared to be monochorionic twins might be the product of a fusion of two originally separate blastocysts. In older embryos the chorion and its inclosed membranes undergo great expansion and this is accompanied by more or less overlapping and invagination of one specimen by another. Thus the question arises as to whether one is dealing with true monochorionic twins or with two individuals that have fused and acquired a common chorionic cavity through obliteration of the intervening wall. In the few instances of twinning thus far described for the pig the possibility of such a fusion has had to be taken into account.

In the second place, it is clear that twinning may occur in a normal environment. In the pig there is a natural test for this point. The functional capacity of the genital tract is revealed by the manner of development of the litter mates which serve as controls. The twinning in this instance occurred in an environment in which the other ova were developing in a normal manner and the uterus itself showed no abnormality. It may therefore be said to have been structurally and functionally normal. We can certainly eliminate the possibility of a delayed or faulty implantation as a causative factor in this case, as we are dealing with a period before implantation normally occurs. During the blastocyst stage the ova are still migrating and attaining properly spaced positions in the uterine cornua. It is only at a later period that the chorion acquires its extensive apposition to the uterine mucosa.

Finally, whatever may be the initial cause or causes, it or they must have operated at an earlier period in development than is represented by this specimen. Here we have the phenomenon fully completed and the twins established as normally developing separate individuals, each of which is just showing the first visible signs of polarity and of an embryonic axis. The twinning took place, therefore, before the establishment of the primitive groove and before the infolding of the embryonic ectoderm to form the neurenteric canal. If the latter be accepted as the analogue of gastrulation of lower forms, we then can not speak of plural gastrulation in this instance. We may go farther than this. It is well known how the surface cells of the blastocyst, i. e., the trophoblastic ectoderm, finally open up and let the inner cell mass come to the surface as a round flattened disk. It is this disk that constitutes the embryonic shield or germinal area, of which there are two in our specimen. Since they have recently come through to the surface and are on opposite

sides of the chorion, it is unlikely that a common disk has divided into two, and it is fairly sure that toward the end of the dilatation of the segmentation cavity there were two inner cell-masses. This, in fact, is what Assheton found in the sheep, and such a division of the inner cell-mass or embryonic node into two is what appears to have happened in the Mateer specimen in man. The fact that twinning in these cases involves fission of the inner cell-mass, presumably at the time of formation and enlargement of the segmentation cavity, does not mean that the twinning process might not occur later in higher mammals, just as it certainly does in lower forms. It is only by assuming plural gastrulation and varying degrees of fission of an established embryonic axis that it is possible to account for certain types of twins, double monsters, and localized duplicities that are occasionally met with.

HOFBAUER CELLS.

In microscopic examination of human pathological placentas, certain conspicuous cells in the stroma of the villi were noticed by the earlier workers and the name "Hofbauer cell" became associated with them through the work of the distinguished German gynecologist of that name. They were generally regarded as an accompaniment of degeneration of the villi and seemed to be particularly characteristic of the early stages of hydatiform mole. Professor A. W. Meyer, in his analysis of the pathological specimens in the Carnegie Collection, threw considerable doubt on their being necessarily indicative of hydatiform degeneration, but was unable to reach any conclusion as to their origin or function. In this matter we are now very much indebted to Dr. W. H. Lewis, who, by applying the methods of studying living tissues, has been able to show that these cells are in all respects identical with clasmato-cytes. Strictly speaking, I should not be describing this investigation under *Pathology*; I have done so, however, because of the long association of these cells with the topic of placental degeneration, although it now turns out that they are a normal element of the tissue.

The opportunity of examining fresh normal material was afforded through the cooperation of Dr. Williams and Dr. Hunner, of the Johns Hopkins Hospital, who, during the course of the winter, removed by operative procedure nine human specimens varying in age from 6½ to 17 weeks, from which the villi were obtained in a living condition. In addition, villi were obtained from full-term placentas. The Hofbauer cells (or placental clasmatocytes) show a marked affinity for neutral red. When fresh living villi are immersed in Locke solution containing neutral red, the stain promptly penetrates into the interior of the villus and becomes accumulated in the numerous vacuoles of the Hofbauer cells, making these cells stand out conspicuously from the other elements of the stroma. In this way Dr. Lewis was able to demonstrate their presence as normal residents of the villus from the second month to full term. They lie scattered throughout the stroma, usually at a distance of from one to three cells apart, in the large spaces between the reticular mesenchyme cells, and show no especial relation either to the blood-vessels or to the Langhans layer. The villi from full-term placentas seem to contain relatively fewer of these cells than the villi from younger stages and here they are elongated in form and are found compressed between the blood-vessels of the stroma. This is apparently due to the greater compactness of the stroma.

Dr. Lewis finds that in hydatiform degeneration, where they first attracted particular attention, the Hofbauer cells are no more abundant than in normal villi, though they are more variable in their distribution. Due to this fact, they may be very abundant in some villi and absent in others.

With their identification as clasmatocytes, there remains no doubt as to their having a function similar to those other clasmatocytes so liberally scattered through the body, both of the embryo and the adult, namely, phagocytosis. As for their origin, transition forms can be found between them and the indifferent mesenchyme cells. It is also possible that they may arise from white blood-cells that have wandered into the tissue spaces, and transitional sizes are found among the round and oval ones down to the size of the white blood-cell. They may, of course, come from both of these sources, and perhaps also from endothelium. There was, however, no evidence of their arising from the Langhans epithelium, as has been maintained by the clinical pathologists.

DEPARTMENT OF GENETICS.

C. B. DAVENPORT, DIRECTOR.

GENERAL STATEMENT.

Owing to the fact that the report for this year closes two months earlier than previous years, this report covers only ten months and takes no account at all of the results of our busiest season, namely, July 1 to September 1. There will naturally be less to tell than in preceding years.

As outstanding results of the year may be cited the further confirmation of the interpretation of the secondary trisomic mutants of *Datura* as due to "fracture" of a chromosome, and the accumulation of evidence that in the secondary the extra chromosome may be a doubled half. Also, the discovery that, at the metaphase, chromosomes lie so that homologous poles are next to each other, or in intimate contact. In the sex problem, "plus" strains of mucors are found to be, in general, relatively stronger reducers of tellurium salts than "minus" strains. Also, evidence is gained for the conclusion that there are other conditions regulating metabolism that determine sex besides the sex chromosome; indeed, apparently a body, which has already gained mature primary glands of one sex, may under extreme conditions have them replaced by glands of the opposite sex. Additional evidence of the germinal complexity of certain traits is adduced in the demonstration that at least 10 genetically different factors determine albinism in maize. Grave doubt is thrown on some evidence recently adduced in favor of the inheritance of the effects of training. Important evidence has been gained of the inheritance of the chemical constitution of tissue fluids in plants. The feasibility of getting family (genetical) history of human applicants for admission to the United States has been demonstrated in 3 European countries. Additions to endocrinology—the science of the organs that play a great part in control of development—have been made, in securing conclusive evidence that the thymus in birds regulates eggshell production and that the reduction of blood-sugar by insulin in doves is followed by increase in thickness of the suprarenal cortex resulting in increased sugar in the blood.

The friendly criticism has sometimes been directed toward this Department that its investigations are somewhat diffuse and not concentrated sufficiently upon a single point. That a certain diffuseness results from a union of the purely theoretical and the applied work must be admitted. Even on the purely theoretical side our work does, indeed, range from chromosomes to endocrines; and this may be regarded as a diffuse program. It is doubtful, however, if a more concentrated attack would take us as far as we want to go. The extraordinary relation that has been worked out between chromosomes and heredity leads to the conclusion that "we are what our chromosomes make us." But we must not forget that endocrinology reveals the fact that persons with very dissimilar chromosomes may become as like as two brothers, in consequence of similar disfunctioning of the endocrine glands. Struck by these remarkable facts, endocrinologists may well insist that "we are what our endocrine glands make us." Between these two views there is, doubtless, no real conflict. If we are what our endocrines make us, our endocrines are what our chromosomes make them. Heredity is the control of the development of the individual. Apparently, in the earlier stages of

development the chromosomes play their rôle rather directly, and among other things determine the quality of cell-tissue or organs which have the special function of determining local metabolism and hence differentiation. Of such organs the endocrine glands are the largest and most striking and stand out most clearly as the great regulators of development. However, we can not neglect the probability that, from very early stages, less obvious and more diffuse cell-groups and tissues are performing a like function. The control of development is a chain with several links; and we shall not understand the mechanism of heredity by confining our attention to any one of the links. Chromosomes, cell-physiology, hormones, and the physical-chemical processes of development are all necessary to an understanding of genetics.

DETAILED REPORT ON CURRENT INVESTIGATIONS.

THE GERM-PLASM.

Since the importance of the chromosomes (Weismann's germ-plasm) in development and heredity becomes constantly more apparent with progress in genetics, it is natural that the investigation of these bodies should have a primary place in our work. Studies are being continued both on the jimson weed, *Datura*, and the banana fly, *Drosophila*, and in both genera the somatic findings in breeding experiments have been correlated with the chromosomal conditions. Cases that do not conform to theory are naturally constantly arising, and the attempt to solve the difficulties they offer leads to important discoveries.

DATURA.

Work on the mutations of the chromosomes of the jimson weed, by Dr. Blakeslee and Dr. Belling, with the assistance of Mr. Gordon Morrison and Miss Betty P. Watt, is leading to new general points of view that can be utilized by all students of genetics and cell-research.

TRISOMIC TYPES; PRIMARY AND SECONDARY.

It has been previously reported that among *Daturas* of the $2n+1$ series there have been found not only primary mutants (of which 12 are expected) but also certain other types with an extra chromosome. The latter are called secondaries. The secondaries now appear to be divisible into at least 3 subclasses. And, first of all, it may be pointed out that studies in pollen abortion carried out by Mr. Cartledge in 1923 had shown that, in all cases investigated, the pollen of secondaries has a higher average percentage of shriveled grains than their respective primaries. This observation, together with the facts presented in our last report, suggested that the difference might be due to some modification of the extra chromosome in the case of the secondaries. It is this suggestion that the past year's studies have confirmed and elaborated.

"In last year's report," states Dr. Blakeslee, "it was pointed out that although the primary mutant Cocklebur appeared to have its extra chromosome in the set carrying the genes for armed and *inermis* capsules, since it threw trisomic ratios when heterozygous for them, nevertheless its secondary Wedge gave only disomic ratios so far as investigated. Thus the Wedge plants tested should have had the formula A_2a if they were like their primary and should have thrown the trisomic ratios $8A:1a$ among the normal and $9A:0a$ among the mutant offspring. Actually, they threw instead 3:1 ratios among

normal and mutant offspring. This year, the heterozygous Wedge plants obtained by crossing an *inermis* Wedge with an armed normal have likewise given disomic 3 : 1 ratios when selfed, although Cocklebur after similar treatment would have been duplex for *inermis* (Aa_2) and would have thrown the trisomic ratios 5 : 4 among normals and 7 : 2 among mutants.

"It appears, therefore, that a heterozygous Wedge plant is always simplex (Aa) for these genes in question. We ventured the suggestion in the last report that Wedge and other secondary mutants might be primaries modified by a deficiency in a portion of the extra chromosome. Dr. Belling, from studies of the sizes and configurations of the trisomes of primaries and secondaries, offers evidence that in Wedge and certain of the other secondaries the extra chromosome is in fact deficient for one half but in addition has the other half doubled. This conception brings into line many of the peculiarities in morphology and breeding behavior shown by secondaries. Of especial interest in this connection is the occurrence of complementary secondaries in the Rolled, Buckling, Poinsettia, and possibly in the Echinus group. In these cases the primary is intermediate in morphological characters between the two secondaries, each of which shows certain characters manifested in a lessened degree by the primary but not shown by the other secondary. In two groups we have found that one of the secondaries fails to give trisomic ratios thrown by its primary. In a single group in which complementary secondaries have been identified, one of the secondaries gives the trisomic ratios shown by its primary, while the other secondary gives only disomic ratios. By following the inheritance of genes carried by the extra chromosome, it seems we are able not only to locate a given factor in a specific whole chromosome, but also to tell in which half it is present. The mutants in which the extra member in the trisome is a doubled half-chromosome ($2n + \frac{2}{2}$) may be considered to constitute our first subgroup among secondary mutants. They differ from their primaries by being duplex for the portion of the chromosome which is missing and quadruplex for the portion which is present in doubled dose.

"A second subgroup of secondaries is represented apparently by Wiry, in which it appears from Dr. Belling's cytological evidence that the extra member in the trisome is a single half-chromosome ($2n + \frac{1}{2}$). In this case we have the secondary differing from its primary by a deficiency of one-half of a chromosome. Wiry, therefore, would be duplex for the missing half-chromosome, but triplex, like its primary, for the other half. It is possible that in one group we have, in addition to the primary mutant, the two complementary ($2n + \frac{2}{2}$) secondaries and also the two complementary ($2n + \frac{1}{2}$) mutants.

"A third subgroup is probably represented by the mutants Nubbin and Spinach. Both throw an extremely high proportion of other trisomic mutants in their offspring, and in both Dr. Belling has found attachments of chromosomes apparently between members of different sets. More evidence is available in regard to Nubbin. This mutant has been placed in the Echinus group on account of its general appearance, its anatomical structure, its breeding behavior (in that it throws a high percentage of the primary Echinus in its offspring), and also on account of the fact that, like Echinus and its secondary Mutilated, it shows a dimorphism of pollen-grains with half devoid of the starch characteristic of normal pollen. Although the pollen dimorphism as well as the morphological appearance indicates that Nubbin has in excess the same part of the chromosome that is in excess in Mutilated, yet the

expressions of the Mutilated characters are less extreme and in certain respects, especially as regards the shape of the capsule, Nubbin shows characters not represented in Mutilated. It is too early to venture a detailed hypothesis in regard to the chromosomal constitution of this type. In view of the foregoing, however, and of the further fact that Nubbin regularly throws two secondary mutants related in appearance to the two $(2n + \frac{2}{2})$ secondaries of Rolled (only less extreme), and of the fact that if Rolled throws trisomic ratios when heterozygous for certain factors for White, Nubbin throws abnormal ratios for those same factors, a relationship is suggested between Nubbin and both the mutant Mutilated and the complementary secondaries of Rolled.

"Possibly all the types of secondaries so far studied involve in their origin the division of a chromosome into halves or unequal segments. It is perhaps significant that all the 6 primary mutants, for which no secondaries had been discovered up to the time of the last report, involved a duplication of the small chromosomes. The fact that the larger chromosomes seem to break in two to form secondaries more frequently than the small ones suggests that the frequency of such breaking is a function of distance, as it is believed to be in chromosomes involved in ordinary disomic crossing-over.

DISTINCTION BETWEEN DIFFERENT WHITES IN DATURA.

"In previous reports it has been stated that the Poinsettia mutant gave typical trisomic ratios when heterozygous for Purple and White if the latter came from a line derived from Washington, but that a consistent increase in the number of White offspring occurred if the Poinsettia was duplex (Pp_2) for a white brought in from a line obtained from Germany. This line has been called a B white and the abnormal ratios B ratios, in distinction from the normal A white from Washington and the A ratios, thrown when two of its chromosomes helped to make up the Poinsettia trisome. Another peculiarity of the B whites is that they are in some way connected up with the spontaneous appearance of Wiry, which appears to be a $(2n + \frac{1}{2})$ secondary of Poinsettia, with the extra chromosome carrying the factors for purple and white. At our last tabulation over 70 cases of spontaneous occurrence of Wiry are listed, and all of these came from parents heterozygous for B whites, but none from parents in which A whites were represented. A preliminary test of whites in nature by means of Poinsettia ratios shows that one found on the island of St. Thomas is an A white, while two others (one from the island of Montserrat and one from near Naples, Italy) are B whites. These two new B whites have also thrown Wirys.

"A more remarkable situation has been found to exist in regard to the mutants Rolled and Nubbin. During the winter we had in the greenhouse 4 series of trisomic mutants made heterozygous for different white lines in an attempt to connect up with the specific chromosomes a number of factors in respect to which these lines differed. The F_2 offspring this summer (June 1924) show that among these whites there are two classes. In one class, normal trisomic ratios occur from simplex (P_2p) Poinsettia, and normal disomic ratios from the other mutants. In the other class, represented by two Whites, both Poinsettia and Rolled throw trisomic ratios, and Nubbin throws a great excess of whites (as many as 7 times the number expected in a 1:1 ratio). These two whites are provisionally called C whites, since, although there are some suggestions of a relationship with B whites, it will not be possible definitely to connect the two before a later date in the summer or in the coming winter. It will not be desirable to present in full the evidence at present available in regard to the different kinds of whites, since critical

tests can not be recorded until later. It may be mentioned, however, that Sugarloaf, one of the secondaries of Rolled, fails to give trisomic ratios, and Polycarpic, its other secondary, has thrown a relatively large number of Wirys, although the number of offspring so far obtained is not sufficient to determine the type of ratio. These facts added to the possible connection which has been indicated between Rolled and Nubbin, as well as the appearance of Wirys from parents heterozygous for B whites, suggest that the peculiarities of these abnormal whites are connected in some way with the Polycarpic half of the Rolled chromosome and the Wiry half of the Poinsettia chromosome. The problem is being further investigated by breeding tests of the origin and nature of Wiry, segregation ratios in the mutants involved, the linkage relations between the genes for Curled and the different types of whites and also detailed cytological study of these mutants and the different pure white races. All the evidence at hand points to the conclusion that the difference between our whites is due to differences involving whole chromosomes or relatively large portions of chromosomes and not to simple gene mutations. The abnormal whites include races which have been taken from the wild, show no excessive amount of pollen abortion, and have obviously successfully withstood the struggle of existence in nature. The discovery of these different whites appears to offer a unique opportunity to study evolution of chromosomes in nature; and for some time we have believed that evolution of organic forms has been conditioned by the evolution of their chromosomes."

EXTRA CHROMOSOMES IN BUD SPORTS.

We have previously reported bud sports or sectorial chimeras in which the generative tissue could be represented by the formula $(2n-1)$, the chromosome deficiency being in the Rolled set. Last fall Dr. Blakeslee found a plant, otherwise normal in appearance, with a branch having leaves and capsules suggesting the Globe mutant in appearance. By sowing seed from the two types of branches and obtaining a high proportion of Globe seedlings from the abnormal branch only, it has been shown that the generative tissue of the branch must have had the formula $(2n+1)$ with the extra chromosome in the Globe set. Probably the extra chromosome of the bud sport arose by non-disjunction in somatic tissue. Since the appearance of the abnormal branch was not entirely typical of the Globe mutant, it is possible that the bud sport was in fact a periclinal chimera having the epidermal tissue with the formula $(2n-1)$ and the subepidermal tissue (which alone was tested by breeding) with the formula $(2n+1)$.

GENE MUTANTS IN DATURA.

The search for gene mutants goes on in *Datura*, since they are essential as labelers of chromosomes and parts of chromosomes. Dr. Blakeslee has already shown that the mutant character Swollen is conditioned by genes in the Ilex chromosome and that the gene for Curled is in the Poinsettia chromosome, more specifically in the Wiry half of this chromosome. Since the genes for Purple and White flower-color are also in the same half of the Poinsettia chromosome, the opportunity is being taken of studying the linkage relations between these two pairs of factors in disomic, trisomic, and tetrasomic inheritance.

MEASUREMENT OF DATURA CHROMOSOMES.

Each of the 12 primary mutants of *Datura* is believed to be due to the addition of a whole chromosome to a different one of the 12 chromosome sets

(I to XII) of this plant. It is clearly important to be able to identify these chromosomes, which are a good deal alike in general form but differ in size. Accordingly, Dr. John Belling has undertaken to measure them in the early metaphase. He reports as follows:

"The chromosomes were measured in the trivalents of $(2n+1)$ plants. Thus the identification of each of the 12 different chromosomes was assured in every case. Camera drawings were made at the constant magnification of 2100. These drawings were measured under a binocular magnification of 3.5. The unit of measurement was 0.5 mm., which corresponded nearly to the practical limit of microscopic detail under the circumstances, namely, a quarter of a micron. The product of length by average breadth was taken for each chromosome of the trivalent. Thirty-six chromosomes were found to be sufficient in any case. Half the necessary measurements were made in the summer of 1923. The time-consuming operation was not the measurement, nor the drawing, but the isolation of the trivalents. The following results were obtained.

"Chromosome I, extra large; size 53 to 55 units. This is the extra chromosome in the $(2n+1)$ form, Rolled. Sugarloaf has been proved to have an extra chromosome of this size. The trivalent of Polycarpic probably comes in here.

"Chromosomes II, III, IV, and V, large; size 37 to 48 units. Differences of size in this class will doubtless appear when the measurements are complete. The extra chromosomes of Wedge, Strawberry, and Maple belong to this class; as probably do those of Cocklebur and Buckling. Elongate and Undulate have not been measured yet, but their trivalents seem of this size.

"Chromosomes VI, VII, and VIII, large medium; size 31 to 32 units. Echinus, Microcarpic, and Mutilated have been proved to belong here, 36 chromosomes having been measured from each.

"Chromosomes IX and X, small medium; size 23 to 28 units. Reduced has this size of extra chromosome, and possibly Spinach also is included.

"Chromosome XI, small; size 21 units. Globe has this size of extra chromosome.

"Chromosome XII, extra small; size 19 units. Ilex, so far as measured, has a trivalent with this size of chromosome.

"In several of these cases only 12 chromosomes have as yet been measured. (Of Glossy and *Poinsettia*, no chromosomes have been measured.) Wiry seems to have a half, or part, chromosome in excess of the diploid number, and to be, not a $(2n+1)$, but perhaps a $(2n+\frac{1}{2})$ plant. Its trivalent, so far as observed, has the form of a V; with a large chromosome at the point of the V, and a small one at one of the ends, corresponding to a large one at the other. Such extra small chromosomes were found by Miss Lutz in *Oenothera*.

ATTRACTION BETWEEN THE HOMOLOGOUS ENDS OF CHROMOSOMES.

"It has been shown that in haploid, diploid, triploid, and tetraploid *Daturas*, the chromosomes at the metaphase of the first maturation divisions are joined in such a way that the homologous chromosomes are in contact at the ends only. (This is not the case in some other plants, such as *Hyacinthus* and *Uvularia*.) In the above-mentioned *Daturas*, the homologous chromosomes are grouped in configurations which agree with the assumption that only corresponding or homologous ends of the chromosomes come together. So that if the ends of a chromosome are designated with regard to their different homologies by *a* and *z* respectively, then *a* joins with *a*, but

not with z , and vice versa. (Junctions are not usually found between non-homologous chromosomes.) About 16 types of configurations in agreement with this assumption have been met with, which comprise nearly all that are possible. Configurations of different kinds which do not agree with the above assumption, but require that one or more chromosomes should have similar ends, are 10 or more in number, and have not been found for certain in haploids, diploids, triploids, or tetraploids. (The apparent occurrence of two triangles in triploids admits of an alternative explanation.)

"In the 11 primary $(2n+1)$ forms which occur in approximately equal numbers in the progeny of triploids, the chromosomes combine to form trivalents in the ordinary ways, only one exception being met with in over 100 cases. Here then, as in triploids, the chromosomes of any trivalent are all az . This gives about 5 possible kinds of configurations, all of which were found. But in some of the secondary $(2n+1)$ forms (which do not appear regularly in the progeny of triploids) configurations occur commonly which are only intelligible on the hypothesis that one of the chromosomes of the trivalent (and only one) has similar ends; that is, is aa or zz . Four of these secondaries gave about 80 trivalents, 52 of which were rings of three. Of the types of configuration of the primaries, only one is excluded from the secondaries on this hypothesis; and it was not found in them. Of the configurations of the secondaries, two kinds occur in about two-thirds of the cases; and these two did not occur in any primary (the one exceptional cell has been already mentioned).

"Those secondaries (except Wiry) which have been accurately measured as to their trivalents have given the same chromosome sizes as their respective primaries. Since the chromosomes of *Datura*, when perfectly fixed and stained, show a central or nearly central constriction in all cases, it seems not improbable that in connection with the crossing over, or segmental interchange, in a trivalent, irregularities consequent on the presence of three chromosomes instead of two should lead to the interchange of non-homologous segments or halves; and it may be supposed that in this case the chromosomes separate more readily at the constriction, as has in fact been observed in *Uvularia*."

Dr. Belling has synthesized his observations, and those of others, as to the classes (by origin) of chromosomal mutations, as follows:

"(1) *Non-conjunction*.—In this case the chromosomes, which normally unite to form one of the bivalents or trivalents, remain separate at the late prophase and metaphase of the first division. This state has been found in triploids (and tetraploids) of *Datura*, *Canna*, and hyacinth. It also occurs in diploid uvularias and has been seen in *Tradescantia*. Such unattached chromosomes may be expected to go to different poles on half the occasions and at other times to the same pole. In the latter case, the effect is the same as is produced by non-disjunction; namely, $(n+1)$ and $(n-1)$ pollen-grains.

"(2) *Non-disjunction*.—This is typically a delay in separating shown by the constituent chromosomes of a bivalent, so that both chromosomes stay on the same side of a cell instead of passing to opposite poles. This delayed separation has been observed at the metaphase in *Canna* and in *Uvularia*; and the results have been seen in *Datura*, where about 0.8 per cent of the pollen-mother-cells of diploid plants showed a division into groups of 11 and 13 chromosomes. This would give about 0.4 per cent of $(n+1)$ pollen. Somatic non-disjunction would increase the number of $(2n+1)$ mutants resulting from synaptic non-disjunction.

"(3) *Non-reduction*.—In this case in *Datura* (and in *Canna*) the bivalents (or univalents, trivalents, or quadrivalents) do not separate into split chro-

mosomes which pass to the poles, but all the constituent chromosomes remain in the metaphase plate, and divide there. Pollen-grains with the $2n$ number of chromosomes are produced. Non-reduction has also been seen in $(2n+1)$ and in $(4n+2)$ *Daturas*.

"(4) *Non-division*.—This term is used (after Bridges) for the omission of the second division in the pollen-mother-cells, pollen-grains with $2n$ chromosomes resulting. Evidence of the occurrence of this would be difficult to obtain in *Datura*, but in *Uvularia*, after forcing in the winter, there was an occurrence of this chromosomal mutation. In one plant of *Uvularia* there had been over 20 per cent of non-division in the one bud examined. This had led to the production of many $2n$ pollen-grains.

"(5) *Detachment*.—This consists usually in one chromosome being left between the two groups, at the anaphase of the first division. It was the most common form of chromosomal change in the plants examined; and has been seen frequently in all forms of *Datura stramonium*, in *Canna*, *Hyacinthus*, *Uvularia*, *Tradescantia*, *Secale*, and *Cypripedium*. Pollen-grains with $(n-1)$ chromosomes result. In *Cypripedium acaule*, observation seemed to show that the $(n-1)$ pollen-grains were later in dividing (for the separation of the vegetative and generative nuclei) than the n grains. The $(n-1)$ pollen-grains and egg-cells do not seem to survive in *Datura*. Somatic detachment would lead to the formation of branches with $(2n-1)$ cells in one of the layers, and if this were the subepidermal layer, the immature pollen-grains of the resulting flowers would be n and $(n-1)$ in equal numbers, as has been found in more than one case.

"(6) *Fracture*.—This is the separation of a chromosome into two parts, usually at the constriction. (A constriction is present in all the chromosomes of all the plants belonging to 7 genera, studies of which are briefly reported here.) It has been observed to take place mostly at the separation of the constituents of the bivalents at the first division. Several instances of this have been observed in *Uvularia*. In one case, the long segment of a chromatid remained attached to one of the homologous chromatids after the latter had moved to the opposite pole, and was present at the anaphase of the second division. In *Datura* it is presumed that fracture of a chromosome occurred in the formation of Wiry, and that fracture at the constriction possibly occurred in the formation of Sugarloaf, Wedge, Strawberry, and Multilated.

"In *Secale*, half of a chromosome seems to be detached in certain plants, so that, as was found in 1922, some rye plants have twice 7, and others twice $7+\frac{1}{2}$ chromosomes in all. The half chromosomes form a small bivalent at the metaphase, one constituent of which is not infrequently detached from the groups at the anaphase. This interesting phenomenon is still under investigation. (The fact has also been observed lately in Japan.)

"(7) *Attachment*.—This is the connection of non-homologous chromosomes at the first metaphase. Such connections have been found in certain $(2n+1)$ *Daturas*, such as Nubbin. In *Tradescantia*, the metaphase chromosomes have been found to be usually connected in fours, in the one plant examined. Such attachment may lead to increase in non-disjunction."

APPARENT DOUBLE DIPLOIDS AND DOUBLE TRIPLOIDS.

"Further studies have been made of the ordinary 'diploid' hyacinths. It has been proved that the different chromosomes which occur in apparent sets of 4 each, and which correspond in size, shape, and position of the constriction, form bivalents, not quadrivalents, at the first metaphase. Also, bivalents of the same size do not attract one another, visibly. Hence the plants are probably not tetraploid, but may be 'double diploid.' A double

diploid is presumed to have originated from a tetraploid, but to have developed preferential attraction between the members of each of 2 pairs in each set of 4 chromosomes. Full proof or disproof of this assumption could be given by Mendelian work with individual genes. In this genus there occur 2 species with half the number of chromosomes of the ordinary hyacinth (de Mol). The short, medium, and long chromosomes of the hyacinth, when measured horizontally, are nearly in the length ratio of 1 : 2 : 4. The triploid hyacinths examined had 6 chromosomes of each size, which formed 2 trivalents, with 3 homologous chromosomes in each. Hence they may be "double triploids." The long chromosomes in the bivalents and trivalents of hyacinths were connected at several points. In cases where careful observation *ad hoc* was made, these points seemed to be homologous; that is, at equal distances from the homologous ends of the bivalents or trivalents."

SEPARATION OF CONSTITUENTS OF BIVALENTS AT THE FIRST DIVISION.

"A special study was made of this in *Uvularia*. Single or double rings were common at the first metaphase, resembling the prophase and metaphase rings of certain insects described so fully of late by Janssens. The configurations and modes of separation, of which a complete series was obtained, can all be accounted for by the hypothesis that the rings sometimes lie in the plane of the cell equator and split then into separate chromatids, and sometimes lie at right angles to this plane, when they separate into 2 half rings whose chromatids remain in contact, temporarily. In other words, the mode of separation seems to be the same as that long known in the Orthoptera, etc."

DROSOPHILA.

ASSOCIATION OF HOMOLOGOUS CHROMOSOMES.

To the studies of Belling on polyploid plant species those of Dr. C. W. Metz on *Drosophila* form an interesting complement. He finds that not only in the ordinary diploid cells but also in the cells of triploid, tetraploid, and octuploid organisms the homologous chromosomes are associated both in somatic and in germ-cells. In somatic prophases such chromosomes are in the above-named types arranged in groups of 2, 3, 4, and 8 respectively, corresponding to the numbers of homologues present in each case.

ARCHITECTURE OF CHROMOSOMES OF *DROSOPHILA VIRILIS*.

The breeding work on this species, a first full study of which was published by the Carnegie Institution in July 1923, has been continued, largely in the hands of Miss Mildred S. Moses. To the 40 mutants described in Publication No. 328 and the 20 reported last year, 44 new mutant characters have been found during the year ending June 30, 1924. Several of these represent remutations or are allelomorphs of previously known characters, but most of them probably represent new loci. They have not all been tested fully as yet, so the exact number can not be given.

Particular attention has been paid by Dr. Metz and Miss Moses to sex-linked characters and to characters in linkage groups IV and VI (dot chromosome) of this species. In the sex-linked group (or the sex-chromosome) 30 loci are now represented by mutant characters. The evidence from these, when compared with that from other species of *Drosophila*, continues to support the view mentioned in last year's report that a genetic relationship (or "homology") exists between the sex-chromosomes of these species, but that rearrangements of genes have taken place. The evidence is not sufficient, however, to indicate how extensive these rearrangements have been.

HOMOLOGIES OF GROUP VI IN *DROSOPHILA VIRILIS*.

Dr. Charles W. Metz has paid particular attention to the homology of group VI in *D. virilis*. He reports:

"The best method of identifying the dot-like chromosome with its proper linkage group would be by means of non-disjunction, but all of our efforts to obtain non-disjunction of this chromosome have failed, and it seems probable that in this species a fly haploid for the small chromosome can not live. If so, *Drosophila virilis* differs in this respect from *D. melanogaster*, in which such flies are viable, as shown by Bridges.

"The question of proper identification of these linkage groups with their respective chromosomes receives additional importance from the fact, noted in Year Book for 1923, p. 98, that two of the characters in group VI resemble characters in *D. melanogaster*, that are known to be in the linkage group represented by the small, dot-like chromosome of that species.

"If our hypothesis outlined above is correct, then the evidence becomes strong that the similar dot-like chromosomes in the two species contain corresponding or 'homologous' genes."

ABERRANT BEHAVIOR OF CHROMOSOMES IN RESPECT TO CROSSING-OVER.

The haploid chromosome group of *Drosophila virilis* consists of one small dot-like chromosome and 5 long, rod-like chromosomes approximately equal in size. Each of these 6 chromosomes is now represented by a group of linked mutant characters. 4 of the groups (including the sex-linked group) include several characters each (from 5 to 30) and the characters in each of them give large amounts of crossing-over, so that the "maps" are long. The shortest is 65 units in length. These 4 groups we consider as representing 4 of the 5 large chromosomes. This leaves 2 groups of characters (groups IV and VI) to represent the remaining large chromosome and the small, dot-like chromosome respectively.

Theoretically the linkage group which represents the long chromosome should include a relatively large number of characters and should give a large amount of crossing-over, while the other (representing the dot-like chromosome) should include few characters and give little crossing-over. Actually, linkage group IV contains 6 characters and gives no crossing-over, and linkage group VI contains 4 characters (2 of which are probably allelomorphs) and gives a small amount of crossing-over (about 5 per cent). Based on the number of mutant characters involved, group IV should represent the long chromosome and group VI the dot-like chromosome. But neither group gives the amount of crossing-over expected of a long chromosome. Apparently a cross-over modifier is present which reduces or inhibits crossing-over in this particular chromosome.

In Dr. Metz's opinion the number of mutant characters is more important than the amount of crossing-over as a criterion in this case, because it is well known that frequency of crossing-over may differ irrespective of chromosome size. On this view linkage group IV should represent the large chromosome and linkage group VI the small one. If this is correct, then group VI behaves according to expectation in that it has few characters and gives a small amount of crossing-over, and group IV is the only one showing aberrant behavior. On the alternative view both groups would be aberrant.

IRREGULAR BEHAVIOR OF REDDISH IN *DROSOPHILA VIRILIS*.

Dr. M. Demerec has discovered in the sex chromosome of *D. virilis* a new yellow body-color which was named reddish, as it was redder than the color

determined by the old gene yellow. F_1 flies from a cross reddish \times yellow are yellow. This suggests that reddish and yellow are allelomorphs; but in the F_2 generation of this cross among 10,971 flies 127 showed the wild color, indicating that reddish and yellow are not in homologous loci. When reddish was crossed with sepia, pilose, or scute, i. e., with factors located at the yellow end of the chromosome, then the reddish-sepia, reddish-pilose, and reddish-scutel cross-over classes were significantly lower than the cross-over classes without reddish, the differences from equality being respectively 7.8, 10.7, and 13.3 times the probable error. This difference could hardly be due to the greater mortality of the reddish classes, because reddish flies are very viable and in the same experiments were as numerous as, or more numerous than, non-reddish flies. When reddish was crossed with factors in the other parts of the sex chromosomes (cross-veinless, vermilion, rugose), the cross-over classes were practically equal to corresponding ones without reddish. While linkage tests show that reddish belongs to the yellow end of the sex chromosome, yet, in spite of a large amount of data, its exact position can not be determined. The results are not in agreement, Dr. Demerec concludes, with a linear arrangement of the gene for reddish in the same line with the other genes. Dr. Demerec suggests the working hypothesis that reddish, an allelomorph of yellow, is located in a duplicated piece of the yellow end of the sex-chromosome.

NEGATIVE RESULTS OF CENTRIFUGING.

To test the possibility that centrifugal force might disturb the normal distribution of chromosomes, females of *Drosophila virilis* were centrifuged when young, by Dr. Demerec, presumably at the time of the reduction division. These treated females were then mated with non-treated males; the matings being so arranged that the behavior of the sex-chromosome could be ascertained through several factors located in that chromosome pair. The matings sepia-crossveinless-short-rugose \times yellow-vermilion-short were used mostly. Sepia (se) is located near the left end and rugose (r) close to the right end of the sex-chromosome, other factors being scattered in between. The behavior of autosomes was not ascertained through the factors located in them, the assumption being made that most of the disturbance in the distribution of autosomes, if not lethal, would at least affect the soma of the fly so that they would be obvious without special matings.

An electric centrifuge, size 2, made by the International Instrument Co., Cambridge, Mass., was used in the experiments. Numerous experiments were made in which speed and time of exposure to centrifuging were changed. Several speeds from the lowest to the highest were combined with different lengths of exposure, i. e., from 5 to 120 minutes continuously and up to 440 minutes at several intervals during the day. From a total of 149 treated females, 11,133 offspring were examined and among them 16 exceptional ones were found, which were caused by non-disjunction of the sex-chromosome. 106 non-treated females, taken from the same stocks as the treated ones, gave 9,334 offspring with 15 non-disjunctions. Centrifuging, apparently, Dr. Demerec concludes, had no influence on the frequency of non-disjunction.

DEFICIENCY IN X-CHROMOSOME.

Among 8,420 offspring from treated (centrifuged) yvs females, which were mated with $scsr$ males, Dr. Demerec found two females which were scr . The simplest hypothesis which accounts for the occurrence of these

females is that the two ends of the *y v s* chromosome of the treated females, homologous to the places where *se* and *r* are located, were inactivated or lost. This process would be responsible for the absence of the dominant allelomorphs of *se* and *r* and would allow for the development of sepia and rugose characters. This hypothesis also accounts for the fact that rugose appeared in females, which is an exception, since rugose is a character limited to males and has never before been observed in females. The hypothesis, however, could not be tested further, because both of the *se r* females were sterile. The flies were husky and well developed, and lived for more than a month, but did not give any progeny. One fly was dissected and large ovaries full of eggs were found. It could not be said that treatment caused the occurrence of *se r* females, because the numbers are too small to draw any conclusion.

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

GENETICS OF X-RAYED MICE.

H. J. Bagg and C. C. Little (also Little and Bagg) have published the results of their application of Roentgen rays to mice. Abnormal-eyed animals have been found in the third and subsequent generations of the descendants of a group of mice treated with comparatively light doses of unfiltered X-rays on 5 consecutive days. From animals thus treated 2 matings, involving wholly different individuals, produced very similar types of abnormality both morphologically and genetically. One was an eye abnormality, which varied from a slightly perceptible defect in one eye to nearly complete atrophy of both eyes. Club feet were also found. There is a general tendency to defective development, as shown by examination of young in utero. The eye abnormality is definitely inherited, is recessive in character (no abnormal-eyed animals having been found in the first generation of an abnormal \times normal cross) and apparently is mendelian in nature.

Dr. Bagg of the Memorial Hospital, New York City, is cooperating with Dr. E. C. MacDowell of this Department in a repetition of the X-ray experiment on mice to see if such abnormalities as are described in the last paragraph can be produced at will by X-rays. Dr. MacDowell reports as follows:

"As before, Dr. Bagg is responsible for the administration of the X-rays; the same dosage and technique of treatment is being employed as in Little and Bagg's experiment. The mice used and the procedure of the experiment differ in the following ways from the earlier experiment: (1) the mice came from 5 and 8 generations of the closest pedigreed inbreeding under experimental conditions; (2) the history and age of each animal is known; (3) each animal gave a litter before it was treated to test its fertility and to provide controls of the same parentage; (4) the number of controls raised is greater than that of the descendants of the tests; (5) treated males and females are mated alternately with treated and control sibs; (6) to increase the number of offspring each treated female is mated on the day she gives a litter and her young are raised by a foster mother.

"So far 15 mice, in three sets, have been treated; more than 1,400 controls in 4 filial generations have been recorded and a few more than 600 descendants in 2 filial generations from X-rayed parents. In one litter from an X-rayed mother by a control father a male was found with one ear short. This male, by 5 full sisters, has given 44 normal young. The second generation has not as yet been born. Among the controls, abnormalities of eye, mouth, or foot have appeared in 4 mice; of these, 3 died early and 1 is a runt. These abnormalities resemble the hereditary malformations discovered by Little and

Bagg, but there is no evidence that they depend upon the same or any specific gene. In an independent side branch of the same strain another abnormality was found that has been tested. This was a defective eye, which at birth looked like the abnormality occasioned by the gene designated by the letter *h*. When crossed to 5 mice carrying the inherited abnormality, that is, of the constitution *hh*, the mouse in question gave all (42) normal offspring; by its own sisters it has given so far 10 young, one of which lacks an eye. Whether or not this may be taken to indicate a heritable basis for this particular case, there can be no doubt but that the abnormal eye in this mouse is not due to the gene *h*.

"The delay in breeding, previously reported as a result of the X-ray treatment, is not verified; the females were non-pregnant when treated and began to breed according to standard when mated immediately after treatment.

"Further cooperation with Dr. Bagg has involved breeding certain selected abnormal families (200 mice) in connection with his discovery of the occasional absence of one or both kidneys as one of the abnormalities displayed by the animals that carry the gene *hh*. Mice with no external indication of any abnormality, the so-called normal overlaps, may lack one or both kidneys, although this abnormality is usually associated with the abnormal eyes or feet carried by the strain. In some cases mice with no kidneys may take in their first meal and live for several hours after birth. This work has been reported by Bagg in the Proceedings of the Society for Experimental Biology and Medicine for February 1924."

ULTRA-VIOLET RAYED MICE.

Mice have been exposed to ultra-violet radiation at Orono, Maine, by Dr. C. C. Little and his collaborators, and, in one family, the F_3 generation has shown a large number of mice that are distinctly smaller than the average. Most such die young, but one has been raised to maturity and when crossed with her normal brother produced 3 normal and 2 small young. The experiment is being continued.

SEX STUDIES.

CONTROL OF THE SEX-RATIO IN CLADOCERA.

Dr. A. M. Banta has continued his attempts to control the sex-ratio of the Cladocera which he has so successfully carried on with the cooperation of Mr. L. A. Brown of the University of Pittsburgh. Earlier results had shown that in crowded bottles the ratio of males was much increased; that most disturbances of the condition of the water in the crowded bottles diminished the proportion of males, but that the addition of carbon dioxide, uric acid, or pressure increased the proportion of males.

During the past 10 months some progress has been made. Thus it has been determined that test animals confined within a glass tube, the lower end of which is covered with silk bolting-cloth and immersed in a "crowded" bottle, produce as many males as those free in the crowded bottle, whereas others in such a tube but without "crowders" about the tube do not produce males. Hence the modifications in the culture medium produced by crowders readily pass through bolting-cloth.

Dr. Banta reports further:

"The usual crowded bottles which produce males contain 10 mothers and 75 c. c. of culture medium. In a similarly shaped vial containing 7.5 c. c. of culture medium and a single mother, males are likewise produced, showing

that the mother in a small amount of culture medium may create the male-initiating situation for herself.

"The changes which occur in the culture medium of a crowded bottle are not specific. Other species of Cladocera may be used as crowders and will produce the same effect as crowders of the same species."

NATURE OF MALE INITIATING FACTORS.

"The effects of aeration especially suggest the possibility of excretory products, possibly volatile excretory products, being involved. To test this out a series of experiments was conducted in which it was sought, if possible, to transfer the volatile substances from crowded bottles to uncrowded bottles. The set-up was as follows: Semi-crowded bottles containing young mothers from a single brood were placed at the beginning and at the end of a long series of heavily crowded bottles (about 20). By means of 2-hole rubber stoppers and glass and rubber tubing, connection was made through the entire series of bottles through which air was slowly bubbled. Other semi-crowded bottles containing young from the same brood were maintained outside of the bubbling series to serve as additional controls. In most cases these 'outside' controls produced a slightly higher percentage of males than the semi-crowded bottles at the beginning of the bubbling series. This would seem to indicate that the bubbling was extensive enough to produce some aeration effect at the start of the series. By the same warrant (if volatile excretory products were present as assumed) the semi-crowded bottles at the end of the series should receive some of these products from the slowly bubbling air-stream (which immediately before had passed through a long series of heavily crowded bottles) and should produce a greater percentage of males than undisturbed semi-crowded bottles. Such did not prove to be the case. The semi-crowded bottles at the end of the series actually produced no more males than those at the beginning of the series.

"This result was not entirely unexpected. Other evidence had already indicated that the male-initiating factors are very transitory, even when aeration had apparently not occurred. The evidence then inclines to the opinion that the excretory products (if such products are the key to the situation) are not necessarily volatile, but rather that they are unstable and that their break-down is facilitated by aeration and by other treatments.

"All the above experimental evidence may be thought of as consistent with the conclusion that the male-provoking condition is a complicated situation in which excretory products conceivably play an important part. Clearly some factor or a balance of factors involved in the culture medium is unstable and easily disturbed."

Other factors that influence crowding have been detected. Temperature is one of these. Semi-crowded bottles have been kept at approximately 15°, 20°, and 25° C. With remarkable uniformity the mothers reared at the lower temperatures produced the most males. Thus, the average percentage of males for 39 experiments at the three temperatures named above were respectively 48, 13, and 5.

Low temperatures and crowding have a common effect—namely, retardation of development; and such retardation may in itself be a factor in male production. But low temperatures have not caused male production in the absence of at least partial crowding. Low temperatures and slow development seem to accentuate the effect of crowding—which is believed to be due to physico-chemical changes arising in the culture medium.

ABNORMAL BEHAVIOR OF SEXUAL EGGS.

In one strain of Cladocera in which males are absent, *sexual eggs* are produced which may develop and hatch without being fertilized—as they have to be in other Cladocera. The chief interest in this phenomenon lies in the problem of the number of chromosomes in these ephippial eggs. It has been generally concluded that these eggs have the reduced (haploid) number of chromosomes and that the diploid number is restored by fertilization. But these eggs are not fertilized, hence the number can not be restored. Are these sexual eggs, then, diploid, and, if so, why do they differ so strikingly from ordinary parthenogenetic eggs? Dr. Banta advances the hypothesis that, just as the Cladocera are tending toward parthenogenesis in other types of reproduction, so perhaps their sexual eggs, which exist for fertilization and as resistant bodies to carry the species through unfavorable conditions, may have begun to lose the first-named function. We have been fortunate in securing the cooperation of Dr. Franz Schrader of Bryn Mawr, who is studying the chromosome history of this race.

THE FUNDAMENTAL NATURE OF SEX DIFFERENCES IN MUCOR.

Miss Sophie Satin, formerly mycologist in the University of Moscow, has been associated with us since January 1 under a grant from the Committee of the National Research Council for Research on Sex Problems. We have started a cooperative investigation upon the fundamental differences between sexes in the mucors, using various biochemical tests. The investigations are as yet in too early a stage to warrant a detailed report of our results. Dr. Blakeslee offers the following preliminary statement of Miss Satin's results, so far as obtained:

"We have demonstrated the existence of physiological differences between races of the same sex, a fact which shows the necessity of testing a large number of individual races of both sexes before reaching conclusions as to the biochemical bases of sex in these or other forms. Most extensive have been our tests of the ability shown by certain living cells to reduce tellurium and selenium from salts of these elements. A total of 264 races (131 Plus, 128 Minus, and 5 Neutrals) was investigated. In all, 7 genera and 13 species are included, and the collection may be considered fairly representative of the group of dioecious mucors. The strength of reaction is indicated by the intensity of pigmentation due to the deposited Te and Se (black for the former and red for the latter element). Grades were recorded by aid of the Color top. It was found that, if the races were grouped according to their power of reduction, Plus races predominated among the strongest reducers (63 Plus to 27 Minus), whereas Minus races predominated among the weakest reducers (36 Minus to 12 Plus). So far as their power of reduction is concerned, there are two groups in our collection. In the first, or larger group, there is a greater or less predominance of Plus races among the strongest reducers and a reversed condition among the weakest reducers. The second group is smaller and shows no essential difference between the Plus and Minus races among the strong and weak reducers. As yet we have found no group in which Plus races are more frequent among the weak reducers or Minus races among strong reducers.

"What significance, if any, is to be attached to the evident greater average reducing capacity of the Plus race can not be told as yet. It is conceivable that the sex differential directly influences the reducing power of the living cells, but that there are other non-sexual factors in respect to which the races of either sex differ which are also of influence. Tests in progress with other reagents upon the same races may throw light upon the question."

SEX-REVERSAL IN ADULT RING-DOVE.

Dr. Riddle has described a case of "sex-reversal" in a dove. This bird had laid 11 eggs at times exactly observed between January and April 1914. In the latter part of 1914, the female on 3 occasions "went broody" without having laid eggs; but incubated eggs of other hens placed under her. In February and March 1915, she was seen to take the part of a male in copulation and in October 1915, coo-ed as a male. She died in December 1917. Autopsy revealed advanced abdominal tuberculosis. Two testes were found, removed, and weighed. The history of the bird was not fully in mind at the time of autopsy and no unusual search was made for traces of ovary or oviduct; which, if present, were obscured by disease.

Dr. Riddle emphasizes the conclusion that the dove probably passed through a stage when its left gonad was partly ovary and partly testis and would have been described as an hermaphrodite gonad; and he thinks that many cases of hermaphrodites in the higher vertebrates have this history. He points out that since sex is a "chromosome-determined" character, this case shows that such a character may become transformed or reversed in its final condition. He suggests, moreover, that other chromosome-determined characters may also have the course of their development altered; and thus heredity may not have the fatefulness usually ascribed to it. "It does not follow that the hereditary factors are transformed, nor that the character-transformation at all affects the succeeding generation."

RIGHT AND LEFT GONADS IN BIRDS AND MAMMALS.

As is well known, the left ovary only is functional in birds. In at least several cases of hermaphroditism in birds it is reasonably clear that the right testis arose on the site of a previously degenerate and never-functional right ovary. On the left side, however, there must have been prolonged stages, Dr. Riddle concludes, at which both a growing or functional left ovary co-existed with a newly growing left testis to form an ovo-testis. Essentially this condition is found in the 11 cases of hermaphroditic fowls in which both right and left gonads have been found present. In other birds all of the 4 known cases having bilateral gonads are found to follow the same rule—right side testis; left side ovo-testis or ovary. Of the 12 best authenticated cases of human hermaphroditism, 7 show a high proportion of testicular tissue on the right side, 2 show the reverse, and in 3 the point is doubtful. "All the evidence," says Riddle, "supports the points: (1) that many cases of hermaphroditism among birds, at least, are really stages of sex reversal, and (2) that the right and left sides of the bird's body, at the point of origin of the sex-glands, are not equally favorable for the growth of testis and ovary; the ovary being favored on the left side and the testis on the right." Dr. Riddle has summarized 12 cases of probable true hermaphroditism that he has found in pigeons. In 9 of them, the right gonad had, or appeared to have, a higher proportion of testis tissue than the left. In 1 case the opposite seemed probable. In 2 cases the relative proportions were not estimated. Of these 12 cases 11 arose in hybrids, 8 of them between different genera.

The atrophy of the right ovary begins in birds at about the time of hatching, and this fact has been considered an expression of unequal femaleness of the right and left sides of the body of the female bird. In all species of pigeons examined by Dr. Riddle (when free from disease and when not kept

too long in confinement), the right testis is usually larger than the left. But under disease, confinement, and hybridity, the proportion of pairs of testes in which the right is larger is diminished. Other observers have concluded that, in birds in general, the left testis is the larger. Dr. Riddle believes that this discrepancy may be due to a failure of the other observers to consider the effects of confinement, disease, and the relation to the bird's breeding-season. To be sure, in some wild birds the left testis is larger during at least most periods of the year, yet in other species examined the left is not larger than the right. Moreover, conditions adverse to testis growth in pigeons usually produce either greater reduction or more frequent reduction in the right testis; and the shape of the left testis more nearly resembles that of the ovary than does that of the right testis.

Dr. Riddle also points out that in hybrids of pigeons the more distant the cross and the larger the proportion of male offspring, the larger the proportion of hybrids with heavier left testis.

BIRDS WITHOUT GONADS.

In 16 cases pigeons have occurred that showed no trace of gonadal tissue; and in 10 of these the birds were healthy or otherwise preclude the hypothesis that the birds had lost their gonads through disease. In 15 other cases one gonad (only) was abnormally absent—evidence that gonadlessness is a developmental phenomenon. Despite this probable congenital absence of testicular tissue, some of these birds developed the behavior and some other secondary sex characters of the male. Dr. Riddle points out the very important bearing of these cases on the theory of the rôle played by the internal secretions of the gonads.

CALCIUM METABOLISM AND SEX.

Earlier investigators having suggested that the sexes of mammals differ in calcium metabolism, Dr. Riddle and Dr. H. E. Honeywell undertook a re-examination of the subject in pigeons with an improved method—that of Kramer and Tisdall. Brothers and sisters of two genera of pigeons were taken (also some male family hybrids). Conditions of diet and sunlight were the same for the two sexes. Results suggest that female pigeons normally show a higher percentage of calcium and magnesium in the blood than do male pigeons.

GENETICS OF SPECIAL TRAITS.

THE TISSUE FLUIDS OF EGYPTIAN AND UPLAND COTTON AND THEIR HYBRIDS.

These studies have been continued along the lines indicated in previous reports. The results of a first study on Pima Egyptian, Meade, and Acala Upland and the F_1 hybrid of Meade Upland and Pima Egyptian cotton have been published by Harris, Lawrence, Hoffman, and Lawrence and Valentine in the *Journal of Agricultural Research* for February 2, 1924. The conclusions of this paper, which represent the results of determinations made in 1920, have been fully substantiated by more extensive subsequent investigations. The high electrical conductivity of the tissue fluids of the Egyptian cotton indicates greater capacity for the absorption and tolerance in solution of electrolytes. Large series of analyses have shown that the chloride content is higher in the tissue fluids of the Egyptian than in those of the Upland plants grown under the same conditions. A detailed report by Harris, Lawrence, and Lawrence is now in press.

Investigations on the sulphate-content of the two types of cotton have shown that while the chloride-content is higher in the Egyptian cotton the sulphate-content is higher in the Upland type. A discussion of these results by Harris and Hoffman is ready for press.

The clear-cut differentiation of the Egyptian and Upland types with respect to physico-chemical properties of their leaf-tissue fluids affords an opportunity for the investigation of the behavior of these physiologically highly important variables in hybridization. Studies of the F_1 and F_2 hybrids are to be investigated in association with each other and with the parent forms during the summer of 1924.

Because of the great susceptibility of all of these characters to environmental influence, a study of the tissue-fluids of the other species of plants in immediate association is essential for valid comparisons.

ALBINISM IN MAIZE.

In cooperation with Professor R. A. Emerson of Cornell University, Dr. M. Demerec has continued the experiments on the genetical analysis of white seedlings. If F_1 data alone are taken into consideration, a conclusion can be drawn from the obtained results that there are at least 10 genetically different factors which determine albinism in maize.

VARIEGATION IN DELPHINIUM.

During the last year, tests of the various factors that affect the development of the chlorophyll were completed and the genetic relations of 7 such were established. Three genetically different factors were found for variegated leaves (V_1-v_1 , V_2-v_2 , V_3-v_3), one for albinism ($W-w$), one for pale-green seedlings and plants ($P-p$), one for piebald plants, i. e., plants with irregular white spots ($Pb-pb$), and one for virescent seedlings ($Vi-vi$), i. e., seedlings which are white at the beginning and turn green later. It was found, also, that the factor for virescent is very closely linked with one of the factors for variegated leaves.

The analysis of mature plant characters as well as further study of variegations has been continued in cooperation with Dr. Metz. The data collected up to this time show that there is one dominant factor which determines anthocyan color in the stem of plants.

VARIATION, CORRELATION, AND INHERITANCE OF EGG PRODUCTION IN THE DOMESTIC FOWL.

Much new material has been organized and these studies are being summarized for publication by the Carnegie Institution; but no new results have been published during the year.

SUSCEPTIBILITY OF MICE TO ALCOHOLIC INTOXICATION.

During the year, the second definitive series of tests of alcohol susceptibility has been started by Dr. MacDowell; in this series the parents and inbred descendants are studied. The reactions obtained from 200 mice belonging to 7 strains have been tested in this series by methods which standardize the age, number of tests, length of treatment, amount of alcohol, criteria of reactions, etc. To simplify the problem, the experiment is now concentrated on 4 of the original 7 strains. Striking similarities have been found between different litters and different generations within the same strain, and differences equally striking between different strains have appeared.

Heredity is a factor in reactions of mice under the influence of alcohol fumes. Before attempting to determine the method of this inheritance it will be necessary to reduce the extraneous influences that act upon the tests and to reduce genetic variability by several generations of selection.

NON-INHERITANCE OF THE EFFECTS OF TRAINING.

Perhaps none of the recent experiments on the modifiability of germinal material has done more to reawaken general interest in this subject than the brief report given by Pavlov of some experiments in which successive generations of mice formed a given association more and more rapidly. Although details of this experiment are still lacking, the tendency in the popular mind has been to apply this conclusion to all training and to arrive at the conclusion that the training of parents is inherited by children. In connection with the study of the effects of alcohol upon the learning ability of albino rats in different generations, Dr. MacDowell made a large collection of records from normal control animals. These had been studied only as controls for the test rats, but they offered also a mass of data bearing critically on the problem of the inheritance of training. An analysis of these records from this point of view has now been completed by Dr. MacDowell. The learning records of 200 normal albino rats, trained for two and three generations to find their food in a maze, were found to satisfy the requirements of this study. The comparison of the different generations led to the unquestionably clear conclusion that the training of the ancestors did not facilitate the learning of the descendants.

GENETICS OF TRANSPLANTABLE CANCER.

Under Dr. C. C. Little's direction, Miss E. E. Jones has been continuing at Orono, Maine, on a steadily increasing scale, the work on isolation of single-factor lines of mice susceptible to implants of the two carcinomas dBrA and dBrB. This has necessitated the breeding and inoculation of a very large number of mice. This year 66 males have been tested, individually; 7 of these are being tested further, the preliminary tests having shown that they possessed certain of the required factors.

Miss B. W. Johnson, also at Orono, has in process of preparation for publication a paper on the genetics of a transplantable tumor, dBrO3. She has shown that this tumor depends for its growth upon the simultaneous presence of three independent Mendelian factors; and that none of these factors is in any case linked with the dilution factor, as is at least one of the genes which underlies susceptibility to the tumor dBrA.

Dr. Little has published a somewhat detailed criticism of Leo Loeb's Individuality Differential Theory, and has tried to show that his classification into the groups of homoio- and hetero-differentials will have to be revised on the basis of our present knowledge of genetics. It also seems that the class of transplants which he groups under the term "syngenesio transplants" is a purely artificial one, and breaks down entirely when genetic rather than pedigree relationships are considered.

Data are also on cards and in process of analysis to interpret Slye's results on the genetics of cancer. Strictly speaking, her work deals with spontaneous rather than with transplanted tumors. It is, however, more convenient in the preparation of this report to include it with the latter than to make a special section for it. Without attempting to enter into a detailed account of the evidence, it may be stated that there is fairly clear proof in Slye's own

work that mammary tumors are genetically distinct from the other types which she has described, and, further, that they depend for their expression upon a dominant mendelizing factor. It also seems that there is evidence that the other types of tumors depend upon multiple factors. While these last two papers are of a destructive-critical nature, they are believed to be justified if they only raise a scientific doubt as to the finality of the individuality differential hypothesis, or the recessive nature of all types of cancer.

Dr. L. C. Strong has continued, at St. Stephen's College, work which he began here on the reactions of mice to transplantable tumors. In general there appear to be genetic factors which permit tumor growth in certain strains of mice only. One sarcoma (Crocker Research Lab., No. 180), however, has been discovered that grows almost uniformly in a number of different strains of laboratory mice. The existence of this sarcoma seems to be an obstacle in the way of the general acceptance of the genetic view. Dr. Strong has, however, found that mice differ in their reaction to this tumor variously. Thus the tumor grows faster in young mice than in adults, whether an inbred albino strain or heterozygous. But in very old mice in which the gonads are not functioning the tumor grows as fast as in immature mice. Mice of certain wild strains castrated while immature were non-susceptible, but those castrated when adult were completely susceptible. Dr. Strong concludes that No. 180 does not disprove the theory that transplantability is controlled by genetic factors, and that the evidence suggests that the gonads have some influence on the assumption of tissue specificity on the part of the host.

THE GENETICS OF SPOTTING.

This field of genetics has been a well-known source of interest and difficulty, and has provided some of the most complex problems that investigators have been called upon to face. As contrasted with the ill-defined spots worked with by other authors, the Orono group has been able to secure two relatively simple forms of spots. A race of black mice yielded a white tail-tip (wtt), also an unpigmented band around the tail "white on tail" (wot). Wtt is recessive to self-color. Occasionally two wtt parents may produce self young, but they are genotypically wtt. Also, occasionally, in this strain the tail-spot is transferred to the belly (with or without white on tail), but the animals are genetically also wtt and breed the same as phenotypically white-tailed animals. Another strain of mice shows a ventral white patch which varies in position and in size to complete absence. Work is being done on the relationship of these types and to throw light on the problem of spotting in general. In this work a new histological method of studying skin pigment has been developed.

GENETICS OF ABNORMAL FOOTED MICE.

Further genetical studies are being made by Dr. Little and his group on abnormalities of feet and legs that followed X-ray treatment of remote ancestors. There is no simple Mendelian inheritance. Apparently two factors, F and L, are involved in production of normal feet and legs—ffll is lethal and ffLl is genotypically and usually phenotypically abnormal; ffLL is usually phenotypically normal. Since all abnormal-footed animals have at least one L factor, two such never give 100 per cent abnormal progeny.

There is no evidence that abnormal-eyed mice are more apt to have abnormal feet than normal-eyed mice. Hence, the factor L has at least a dif-

ferent effect upon the two genetic combinations LL (eye abnormalities) and ff (foot abnormalities). This suggests that l and f are not identical.

In the line that has given abnormal-eyed and abnormal-footed individuals arose a polydactyl female, which, when crossed with her normal-footed brother, gave 4 young, 1 polydactyl. The same polydactyl mother mated to her polydactyl son gave 11 young—2 polydactylous, 2 club-footed. The polydactylous father of the above was crossed with unrelated, normal-eyed females and sired 46 young, all normal eyed and normal footed. Dr. Little concludes that, in this strain, polydactylism is not dominant.

SADDLE MICE.

The study of the localized shortening of the hair on back and flank known as "saddle" is being continued by the Orono group, but meets with difficulty because of heavy mortality or sterility of the most typical examples of these mice.

SPONTANEOUS ABNORMAL EYE.

A mutant (called r, reduced) in mice is being studied by Miss Elizabeth Jones at Orono. In the reduced eye both lens and eye opening are affected and total blindness sometimes occurs. The indications are that it is a recessive, sex-linked character; but, since no true breeding strain of abnormal-eyed animals has been produced, modifying factors may also be involved.

RABBITS.

Professor H. D. Fish of the University of Pittsburgh, as Associate of this Department, has continued his researches, on the unique strains of rabbits, which he has been carrying on since 1917. He reports the production of a truly homozygous white Dutch strain. By selecting the phenotypically whitest individuals of his whitest strain he secured a line which is the whitest yet produced (having black about eyes and tail only) which has varied not more than 4 per cent through 3 generations.

Professor Fish has devised a new method of describing the distribution of color areas. The coat of the living animal has been marked into squares and the corresponding forms and sizes of such squares found when the pelt is removed and stretched. By this means the descriptions of the various investigators, whether made from living animals or from stretched hides can be compared.

GENETICS OF THE THOROUGHBRED HORSE.

During the year studies were continued in the genetics of the thoroughbred horse by Dr. H. H. Laughlin in collaboration with Mr. Walter J. Salmon. Researches were undertaken in England, the home of this breed of horse, and special research was begun into the methods of mate selection followed by the English breeders. A personal visit was made by Dr. Laughlin to several of the most important English studs, and finally a field worker, Miss May Carter, was secured for the purpose of gathering biological data concerning soundness, speed, and stamina of the several members of selected strains of horses. Headquarters have been provided for her at the rooms of the Eugenics Education Society, 11 Lincoln's Inn Fields, London.

In Kentucky, in collaboration with Professor W. S. Anderson of the Department of Genetics of the University of Kentucky, Mr. A. R. Quarles was employed as field worker for making studies on the family strains of selected groups of American thoroughbreds.

A third field worker is maintained with headquarters at the Eugenics Record Office, making similar family studies of the horses which compete in the great races held near New York City.

The work in horse genetics is now well established with a staff comprising Miss Alice Hellmer, the principal scientific assistant, and three field workers and one office assistant. A highly specialized library on horse genetics is being built up, and the whole work organized for the principal purpose of securing facts in reference to the family distribution of soundness, speed, and stamina, and the inheritance and variability of these qualities, and to the principles of mate selection followed in building up and maintaining highly specialized strains within the breed of Thoroughbreds.

Data are being critically collected and systematized so that such questions and problems as the following can ultimately be answered or worked out:

1. Have the best stallions been consistently put to the best mares, or has the matter of fashion and reputation played an undue part?
2. Has the type of inbreeding been a definite factor in speed production?
3. What influence has the age of the sire, the age of the dam, the order of birth, and the interval between births played in speed production?
4. The working out of a near-kin index for speed in which the probable hereditary speed constitution of a given animal can be predicted within a definite range of error.
5. The collection of pedigrees showing the family distribution of definite unsoundnesses, which now are known to run in families, for the purpose of seeking more definite rules of inheritance.

TWINNING IN SHEEP.

In 1924, the same ram was used as in the past 2 years (No. 379, a single of the twin strain). There were born 7 singles, 10 twins, 2 triplets, and 1 quadruplet (so large that they caused the mother's death). This is an average of 1.85 young per mother as contrasted with 1.75 last year and 1.38 the year before. The ram, increasing yearly in strength and vigor, has thus at the same time increased in fecundity. This again emphasizes the importance for multiple births of a vigorous male.

Through the kindness of the estate of Dr. A. Graham Bell, this Department was presented with two ewes from Dr. Bell's famous multi-nippled twin-bearing flock (Nos. 28-29 and 25F), both 6-nippled twins. The latter, having been mated to the best sire of the Bell flock, bore 6-nippled twins in March.

HUMAN GENETICS.

HEREDITY IN ARISTOGENIC FAMILIES.

Dr. H. J. Banker has concentrated on the collection of data for a study of inheritance of special scholarship, using the school records of the town of Huntington and compiling pedigrees of the families involved. At this time about 100 families are involved, comprising 450 students. Only families are considered for which there are records for both parents and one or more children.

HEREDITY IN CACOGENIC FAMILIES.

Dr. A. H. Estabrook has continued his field work in Virginia and in Kentucky. His study of the Indian-negro-white racial complexes in the southeastern States has been completed. This included a study of the "Issbies" of Amherst County, Virginia, in cooperation with Sweet Briar College. The

group is segregated by geographical and social barriers and is much inbred. On account of much promiscuity, in certain sections accurate pedigrees have not been obtainable. Other groups like the "Issies" have been examined in Amherst, Rockbridge, Halifax, Charles City, New Kent, and King William Counties, Virginia. In all cases the Indians are mixed with negro and white bloods. In Robeson County, North Carolina, were found the Croatans, a group of 10,000 Indians, partly diluted with negro. In Marlboro County, South Carolina, are two groups of Indians, partly Croatan, partly Cheraws. They number 3,000 and are partly mixed with whites and with negro. Similar Indian-negro-white mixtures are found at Pontiac and at Summerville, South Carolina, and in Butler County, Tennessee. These groups present a problem, partly on account of the mental defect present in many of them; partly on account of the social barrier which causes these whites, because of traces of Indian and negro blood, to be segregated.

The major field operation in the mountains of Southeastern Kentucky has been continued. The genealogies of about 20 of the old families have been compiled and data collected about each member of these families. Due to the loss of the more ambitious and keener persons by emigration, the stock that has been left behind has deteriorated. This appears to hold only for the heads of the creeks of the Kentucky River—not for the mountain areas with more fertile valleys and better transportation. Mental testing was carried on in the schools of the area and the economic factors involved in migration have been considered.

A cursory survey was made of the mountainous region east of Knoxville, and much use was made of the records of Maryville College, which has served the county for many years.

ENDOCRINES IN DEVELOPMENT OF HUMAN TRAITS.

A study was made by the Director of 100 mongoloid idiots, to throw light on their striking resemblance. Work was done at Letchworth Village with the cooperation of Dr. C. S. Little, superintendent; at Vineland, with the assistance of Prof. E. R. Johnstone of the Training School and Mr. Moore of the Girls' Home; at Elwyn, Pa., Dr. Martin W. Barr, superintendent; at Waverley, Mass., where every facility was afforded by Dr. W. E. Fernald, and at Randall's Island, Dr. C. G. McGaffin, Medical Superintendent. A series of measurements was made on children at the Orphan Asylum of Brooklyn under arrangements made with Miss L. Elizabeth Thomas, superintendent. The latter series serves as control. Miss Anna W. March assisted in the reduction of the data. Some results of these studies were presented in May before the American Association for the Study of the Feeble-Minded.

INHERITANCE OF EXCEPTIONAL INTELLIGENCE.

A study of the family histories of 90 families of students at Public School No. 165, New York City, who showed a high-intelligence quotient by the Binet test, has been made by Miss Grace Allen, working under my direction and in collaboration with a committee of Teachers' College, New York City. These histories are now being prepared for publication.

GENETIC CONSTRUCTION OF THE AMERICAN POPULATION.—NATIONAL IMMIGRATION.

From August 8, 1923, to February 14, 1924, Dr. H. H. Laughlin was in Europe making a study of American immigration at its sources. The study was facilitated by Dr. Laughlin's appointment by the Secretary of Labor as

United States Immigration Agent to Europe. In all, 11 countries, namely, England, Holland, Germany, Sweden, Denmark, Belgium, France, Italy, Switzerland, Spain, and Algiers were visited. The work divided itself into two sections: first, experimental studies in personal and family history records of would-be emigrants to the United States; second, through the American consuls, securing first-hand facts about the historical, anthropological, social, economic and political conditions which were and are influencing emigration to America, with particular reference to the constitutional capacities of the specific classes affected.

The investigations of the personal and family histories of applicants for the American visé of passports to America were made with the collaboration of the consuls under the theory that the viséing agent is entitled to sufficient knowledge concerning applicants. Four histories were thus worked out in Belgium by Madame Varchaver, field worker; 4 in England, with the collaboration of the Eugenics Education Society, by Miss E. E. Mudd; 4 in Sweden with the State Institute of Race Biology, Herman Lundborg, Director, by Guimar Dahlberg, field worker. The information obtained included (a) short biography, individual analysis card, conduct, community reputation, occupations, achievements, moral and social instincts, temperament; (b) physical, physiological, pathological, anthropometrical, and racial data, (c) tests of literacy, general mental ability, special talent, and defects; (c) pedigree chart and descriptions of the near kin of the applicant. Provision was made for an analysis of the case showing (a) the probable development and values of the individual gauged by his juvenile promise and by the stock from which he springs; (b) whether the possible offspring of the individual would constitute an asset or a debit to the American nation, based on the average inborn physical, mental, and moral qualities of the family stocks already existing in the United States. The study led to the conclusion that, because of the desire of the applicant to emigrate to the United States and because of the increasing value placed on this privilege on account of the policy of restriction of immigration adopted by this country, it will be feasible to secure necessary data concerning the applicant, by agents of this country; though special cases may arise where obstacles would be placed by a foreign government to the way of making the necessary inquiries. It was concluded from these studies that the cost of making them could readily be borne by the applicant; also that a decision of the question whether a would-be emigrant meets the individual and family stock standards set by American law can be determined much more surely in the home territories of the emigrant than in the isolated and foreign environment in which he is placed after he arrives in America. From the biological viewpoint, it was demonstrated by these researches that if our legal standards of individual and family stocks were sufficiently high, immigration could be made to add to the family stock values of the American people.

In making the studies described above, special courtesies were received from Dr. A. Govaerts, director of the Belgian Record Office, established at the Solvay Institute. Most of the 128 consular offices of the United States in Europe and the Near East rendered assistance in the study; and of them 25 were visited by Dr. Laughlin. Data concerning immigration conditions in their territory were received from most of the consulates. The results of this study are being published as a hearing before the House Committee on Immigration and Naturalization, March 8, 1924, under the title *Europe as an*

Emigrant Exporting Continent and the United States as an Immigrant Receiving Nation; A Preliminary Report of Field Investigations Concerning Present-Day Human Migrations, with Particular Reference to Racial and National Fortunes, Statistically and Biologically Considered. The manuscript comprises 152 typewritten pages and is accompanied by 29 charts and tables.

THE PHYSIOLOGY OF REPRODUCTION AND DEVELOPMENT.

NUMBER OF CORPORA LUTEA IN MICE AND ITS MODIFICATION BY ALCOHOLIZATION.

In order to get a more adequate criterion of the activity of the ovaries than is given by size of litter (influenced as the latter is by failure of fertilization and by early intra-uterine deaths), Dr. MacDowell has been counting corpora lutea by the surgical technique described in Year Book No. 22, p. 117. As a result of prolonged testing of the method the following conclusions are warranted: (1) the operation does not affect the number of young subsequently born; (2) it does not increase the number of young found dead at birth; (3) the operation may safely be repeated many times on the same mouse; (4) the method is entirely satisfactory for determining the number of ova produced under given experimental conditions and of prenatal mortality under especial modifying conditions.

"The analysis, by this method, of the influence of relatively light doses of alcohol upon reproduction in mice has been completed. Mice treated daily with the standardized 'light' dose of alcohol fumes for an average of 4 months before their first pregnancy, and after this, on all but the last few days of the succeeding two or three pregnancies, produced as many corpora lutea as their untreated sisters. In 48 test operations the corpora lutea averaged 9.95 per pregnancy; in 49 control operations, 9.90 per litter. In these matings the same normal male was used for the treated and control sisters from the same litter. Counting only the young born alive, the litters from treated mice averaged 5.79; those from the controls, 5.79. Since the litters from the treated and control females were started by the same average number of ova, and the number of young successfully surviving birth averaged the same in each group, it is clear that the prenatal mortality in each group must also have been the same. In the last Year Book (p. 117) certain general statements were presented as to the independence of the number of days between successive ovulations (the oestrous cycle) and this alcohol treatment. This may now be expressed more exactly by the following summary: 106 oestrous cycles in unmated treated mice averaged 9.3 days; 89 cycles in the untreated sisters averaged 9.5 days. The difference is insignificant. The same result is given by each four strains taken separately, as well as by each pen of treated females compared with the controls living in the same pen.

"Although the number of cases is not large, the practical identity throughout of test and control averages speaks for the adequacy of the data. The findings here presented, supported by certain others not cited, lead to the general conclusion that three and four months of a daily alcohol treatment called 'light,' but sufficiently strong to produce complete anesthesia in certain mice every time, has had no effect upon the reproductive processes of the mice so treated.

"This result resembles that previously obtained by the relatively light treatment of albino rats. Work upon the next step, the testing of the effects of heavy doses, is in progress. In this experiment every mouse is made dead drunk every time, starting at weaning. The unit experiment consists of 4 females from one litter, 2 of which are treated; these are mated at weaning with a normal male sib, whose fertility has been proven, in order to obtain

pregnancy as soon as possible. As the attention is focussed upon the corpora lutea counts, the young are always killed at birth and the mother immediately remated. Beside the comparison with the untreated females, the activity of the ovaries in the early part of the treatment is compared with their activity after prolonged treatment. So far 39 operations have been performed upon 25 treated females; 46 operations on 26 controls. The average number of corpora lutea in the treated mice is 9.50 per ovulation; in the control mice, 9.02 per ovulation. The average number of mice found at birth from the treated mothers is 4.93 per litter; from the control mothers, 6.02 per litter. This is an indication that the activity of the ovary is probably not affected by this treatment, and that the smaller number of young born is due to uterine conditions. There remains the possibility that the germ cells themselves are damaged and that the direct effect of the alcohol upon the developing embryos is not the whole explanation. To test this point an experiment is being carried out in which the males alone are treated. The criterion used is the prenatal mortality, based upon corpora lutea counts, in the same females when mated alternately by treated and control males from the same litter."

ABNORMAL YOUNG IN ALCOHOL EXPERIMENTS.

"Among the offspring of one family of mice treated with alcohol were found striking lethal abnormalities of the lower jaw and head that closely parallel the otocephalic monsters described by Wright in guinea pigs. This character varied from a reduction of the lower jaw that left just a pin-point mouth, to the deformation of the whole snout region, forming a cyclopiian monster with ears drawn together ventrally and with extended proboscis. In some cases the eyes in these monsters were normal, in others one or both showed the condition characteristic of the inherited eye-abnormality in the X-ray lines; this abnormal-eyed condition has also been found in this family associated with a normal jaw.

"The first appearance of the otocephalic abnormality was in the offspring of an alcoholized female; five cases were recorded. The abnormality reappeared in the offspring of the surviving children, which had also been treated. A treated sister of the first mother threw the same unmistakable abnormality. Such a dramatic effect, found in two generations of treated animals would supply the most appealing evidence of the deleterious results of alcohol treatment, had this evidence not been cancelled by the appearance of the same abnormality among the immediate controls. Two untreated sisters of the first two mentioned gave otocephalic, or jawless, young, and in the fourth inbred generation from another untreated sister, other jawless young appeared.

"In the large number of young born during alcoholic treatment by mothers treated with alcohol, there is no evidence that the alcohol has been the cause of any abnormality."

REGENERATION OF THE OVARY IN MICE.

In some studies on fecundity and of transplantation of ovaries, the Director was led to make an extensive series of ovariectomies on mice belonging to our highly inbred strains. About two-thirds of all operations were followed by a more or less complete reappearance of an ovary. Regeneration occurs equally when the mice are only a month old or 3 or 4 months old. It may take place within a month or two after operation but the proportion of regenerated ovaries increases until 6 months have elapsed. Adhesions and minor infections do not inhibit the reformation of the ovary and such reformation is neither facilitated nor inhibited by pregnancy. The evidence is practically complete that we have to do in most cases with a new ovary and

not merely the regeneration of a fragment left behind. The results favor the view that the ovary may be formed at almost any time in the life cycle of the mouse from the peritoneum.

THYMUS AND EGG-SHELL PRODUCTION.

In the investigation of a peculiar type of reproduction disturbance in pigeons Dr. Riddle has discovered that the thymus gland—long the “enigmatic organ” of the human body—is indispensable to the production of the egg-envelopes. This action he believes to be due to a hormone, which he has named thymovidin. He summarizes his results as follows:

“A prolonged study of the etiology of several types of reproductive abnormalities in pigeons has resulted in the isolation of one type of disorder which is readily corrected by the oral administration of ox thymus.

“This particular type or syndrome involves: Eggs with yolks of normal size but deficient in shell and albumen; frequent reduction of normally paired ovulations to single ovulations; diminished fertility, and a restricted hatchability of eggs. In addition, birds showing these abnormalities initially had shown quite normal reproduction. All of the five birds showing these abnormalities were found at necropsy to have extremely small thymi.

“Only birds of the particular type described were affected by thymus administration. Dosage with other substances, including a few tests of other desiccated tissues, had no effect on this type of abnormality.

“Complete thymectomy is difficult to obtain in pigeons and there are many sources of error in evaluating the completeness and the results of the operation. From one partially successful test data were obtained in conformity with Soli’s more extensive but inadequately interpreted results with thymectomized fowl.

“The whole of the data seems to demonstrate the presence in the thymus of a substance having a highly specific action on the oviduct of birds—and presumably, of all those vertebrate animals which secrete egg-envelopes. The substance is indispensable to the production of normal egg-envelopes. It is apparently of the nature of a true hormone. To characterize it with reference to its place of origin and the principal point of its action the name *thymovidin* is suggested.

“Several facts indicate that thymovidin is only very slowly destroyed in either the blood or the digestive fluids; but no step in its isolation from thymic tissue has been attempted.

“Though not necessary to the life of the individual, thymovidin would seem essential to the perpetuation of those vertebrate species whose eggs are protected by egg-envelopes. Such animals were the ancestors of mammals and thus mammals also probably could not have come into existence without the thymus.”

RELATION OF BLOOD SUGAR TO SIZE OF THYROIDS AND SUPRARENALS IN PIGEONS.

Dr. O. Riddle and Dr. H. E. Honeywell with the assistance of Mr. J. R. Spannuth obtained the following results as to blood-sugar content in a fraternity of pigeons.

“In a group of brother and sister hybrids it has been found that the group of birds giving abnormally low blood sugars had large thyroids and large suprarenals. Those giving abnormally high blood-sugars had small thyroids and small suprarenals. Less conclusive evidence indicates that large gonads are associated with the large thyroids. An adequate interpretation of this relationship is not attempted. A suggestion is made concerning this sugar-glandular association. The results probably assist an understanding of

cases of normal individuals of the same race or strain which show consistently low or consistently high blood sugar. The data supply an unusual indication that thyroid and suprarenal are both in some way concerned in the establishment of the normal concentration of sugar in the blood."

In a second study some new light was thrown upon the interaction of the suprarenals and pancreas in the regulation of the carbohydrate metabolism. Following earlier studies, reported last year, in which it was found that ovulation could be suppressed in pigeons by an appropriate dosage of insulin, it has now been learned that very heavy or quite continuous insulin dosage results in an hypertrophy of the suprarenal glands. This study was carried out by Dr. Riddle with the assistance of Dr. H. E. Honeywell and Mr. Walter S. Fisher, and has been summarized as follows:

"The earlier reported fact that normal pigeons survive disproportionately large injections of insulin has been further confirmed and is probably of significance to each of the results described here. The administration of single heavy doses of insulin, or of repeated less heavy dosage, usually results in suprarenal enlargement which is measurable by weighing.

"Some evidence was obtained indicating that repeated heavy insulin dosage is followed within a few days by a lessened capacity of this insulin dosage to maintain the blood sugar at a low level during the usual length of time. Such dosage is also often followed within 6 hours by abnormally high sugar level. It seems probable that the time of appearance of the most striking of these irregularities is approximately the time at which the enlargement of the suprarenals is demonstrable. Among the animals studied by us it was mainly those with largest suprarenals which either died or showed most pronounced effects after administration of large amounts of insulin. To the extent that data obtained on the bird are applicable to the human, these results supply an additional reason for avoidance of heavy insulin dosage in man.

"The results indicate that the suprarenals of normal doves make one response which is not merely immediate and quickly transitory to insulin administered heavily or repeatedly. This delayed or prolonged response takes the form of enlargement, certainly involving hyperplasia of the cortex, and is usually associated with an abnormally increased concentration of the sugar of the blood. The data obtained are in harmony with the view that such insulin administration is accompanied by an increased production of adrenin."

OTHER INVESTIGATIONS.

INVESTIGATIONS ON THE TISSUE FLUIDS OF THE CEREALS AS GROWN UNDER DRY FARM AND IRRIGATION AGRICULTURE.

Some progress has been made in the statistical elaboration of the results of experiments presented in preceding reports.

METHODS WITH PLANT FLUIDS.

Considerable progress has been made in the development of methods suitable for dealing with various genetic and physiological problems. Mr. and Mrs. Lawrence successfully employed the Folin-Wu method for reducing sugars on extensive determinations on the tissue fluids of Egyptian and Upland cotton in collaboration with Doctor Harris.

Lawrence and Harris have published the tests of a rapid and accurate method for the determination of chlorides in plant tissue fluids (*Journal American Chemical Society*, June 1924).

The method has been practically used in several hundreds of determinations on native vegetation of the, in part, highly saline Lake Bonneville Basin (see previous report) and in investigations on Egyptian and Upland cotton.

ADMINISTRATIVE RECORD.

ARCHIVES OF THE EUGENICS RECORD OFFICE.

Dr. Elizabeth B. Muncey has continued as archivist, and has been assisted by Misses Helen Bowen and Margaret Martin as indexers. An estimate of the extent of the records and the index as of June 30, 1924, is as follows: 1,695 books in the archives; Field reports, 61,242 sheets; Special traits file (A), 27,413 sheets; Record of Family Traits (R and M files), 6,580 parts; 1,040,471 cards in the index involving several million references. A satisfactory flow of data of good quality is maintained through contact with educational institutions. Over 2,000 Records of Family Traits (many comprising also individual analysis cards) have been received through such collaboration, in the 10 months ending June 30, 1924.

TRAINING CORPS.

Arrangements have been completed (June 30) for giving training in field investigations to 10 women and 2 men. Owing to various considerations it seems probable that this is the last year of the Training Corps, which has proved in the past an indispensable adjunct to research in eugenics, and will have trained about 258 persons, many of whom are still making investigations in eugenics and related fields. To these field workers most of our 60,000 sheets of field reports are due.

SPECIAL ACTIVITIES OF AND CHANGES IN STAFF.

The principal change in staff is the resignation of Dr. J. Arthur Harris who has been connected with the staff of the Department of Genetics for 17 years and leaves us to take charge of the Department of Botany of the University of Minnesota. Dr. Harris has been extraordinarily prolific in his researches and in them he has shown an unusual versatility which has permitted him to assume a leading position in research in biometry and in the physico-chemical properties of plant tissue fluids.

As reported elsewhere, Dr. Laughlin spent 6 months in Europe on immigration studies.

GEOPHYSICAL LABORATORY.¹

ARTHUR L. DAY, DIRECTOR.

NEW METHODS OF STUDY.

As soon as the attempt is made to apply exact criteria to the ill-defined units and masses of the earth's structure, the problems of delimitation, identification, and characterization of these bodies become important. It is not practicable, for example, to advance along the whole front at once. The simpler relations require first to be attacked, and the establishment of each of these adds to our power of analysis of the greater problem beyond. If it be decided to start with individual crystal units (the mineral components), then we quickly discover that natural crystals are almost invariably chemically complex, and their physical properties in consequence differ from those of pure, chemically defined substances. We discover also a considerable degree of physical complexity due to the fact that they are generally formed under pressure in the presence of gaseous or volatile substances which are readily soluble therein, and that such solution profoundly modifies the physical properties, the thermal constants, and the chemical constitution. It is often possible in the laboratory to prepare the pure substances (synthetic minerals) which thereafter serve as standards of comparison through which to measure the physical properties and modifications of the natural minerals of similar type and so to give to them a quantitative characterization or identification.

As the experience of the Laboratory has widened, more of these physical properties have become available for such determinations, until not only the identification of individual minerals and also limited mineral groups is readily established, but the solution relations of the individuals comprising the group can often be fixed by optical means without entering upon long processes of chemical examination. Optical properties which can be determined microscopically are so helpfully related to other physical and chemical properties that they themselves become subjects of productive research and of increased usefulness in the study of unknown material.

For example, during the past year a successful optical study has been made of the minerals, as well as the conditions of their formation in crusts over oxidizing pyritic ore, from an occurrence at Bisbee, Arizona. In like manner some half-dozen new minerals have been identified optically in the fumarolic and geyser deposits of the Katmai region and of Sonoma County, California. In connection with the identification of these, there has been prepared a complete set of the magnesium sulphates of the system $\text{MgSO}_4\text{--H}_2\text{SO}_4\text{--H}_2\text{O}$, and their conditions of formation, as well as the physical properties of the pure types determined for use as constants of comparison.

Optical dispersion is a well-defined physical property which has been rarely used for the identification of mineral substances; nevertheless it is highly sensitive for the detection of certain compositional and constitutional changes which can thus be determined microscopically. In a case of doubly refracting substances the principal refractive indices are subject to wide differences of dispersion. Excellent examples of the character of these dif-

¹Situated in Washington, District of Columbia.

ferences and of the method of such measurements are contained in the paper on $\text{Fe}_2\text{O}_3\text{--SO}_3\text{--H}_2\text{O}$ (reviewed on page 147, Year Book 21). Other illustrations of the effectiveness of this method of approach will appear in a forthcoming paper on the acmitic pyroxenes, in another on arsenic compounds from fumaroles, and in still another on the lead oxides.

Not only is the absolute amount of the dispersion variable, but its relative magnitude in different parts of the spectrum varies also, as will appear from measurements on zircon, sphalerite, magnesium oxide, as well as piperine and Canada-balsam mixtures, upon which work is now in progress. This last quality has a special importance in the case of isotropic substances where the refractive index has less significance. Again, in the identification of organic liquids these various, easily measured optical properties are readily correlated with density and boiling-point by means of graphs and numerical relations. Charts and numerical tables covering practically the whole range of optical measurements on organic compounds have been prepared and have proved very helpful.

Perhaps one of the reasons why dispersion is not more frequently used is because the existing data on the subject are somewhat confused. Many dispersions are too great to be represented accurately by graphs, and widely different wave-lengths have been chosen, but these do not necessarily lead to confusion. By means of a table already published and a comparison method which makes use of a few standard dispersion curves, interpolations can in fact be made with a minimum of effort and prove most serviceable.

A further interesting application of the dispersion method occurs in the optical determination of olivine, one of the important phenocrysts in volcanic rocks. Olivines are found upon analysis to show such large amounts of ferric oxide and other constituents, not previously taken into account in optical methods of determination, that a study has been made of the refractive effects of these constituents. Acmite has been found to be so rich in ferric oxide that it affords a basis for calculating the effect of ferric oxide on the optical properties of silicate minerals.

VOLATILE COMPONENTS OF ROCKS.

The study of the volatile materials contained in the rocks of the earth's crust, and especially of the gases obtained from volcanoes or given off by lavas when heated in vacuo, has been continued. It began with the studies made of the gases collected at various times from molten lava at Kilauea, but opportunities for such collection are rare and it is of importance, therefore, to know how much information can be gathered from an examination of the gases which the same lava yields when heated to melting in vacuo. These data are nearly completed for Kilauea, but the development of one unexpected relationship makes it desirable to examine a few more specimens before publishing.

The latest extruded material from Lassen Peak, California, has also been examined and the data published in part.¹ It seemed advisable, however, to make a rather thorough study of the Lassen rocks, both chemically and with respect to their content of volatile matter. With this in view, the region was revisited in August 1923 and a fairly complete suite of lavas secured.

¹ Day and Allen, Volcanic Activity and Hot Springs of Lassen Peak. Carnegie Inst. Wash. Pub. No. 360.

Some 20 of these have been analyzed, with particular attention to the "inclusions" which are abundant in the later lavas from Lassen Peak. It may be noted in passing that both chromium and molybdenum have been found in the Lassen material. A tentative hypothesis regarding the origin of the quartz basalts has also been formed and is being tested.

Dr. E. O. Hovey and Professor Lacroix have very kindly supplied us with material from Mont Pelée, Martinique, and this has been rather completely analyzed. The specimens, with possibly one exception, are all from the 1902-1903 eruption period. The material came from the "base of the spine," the spine itself, a breadcrust bomb, and a pumice carried down by the nuées ardentes of July 9, 1902. Chemically the specimens are almost identical. Chromium and molybdenum are absent. The gas-content varies with the "heat treatment" to which the material may have been subjected. The baked holocrystalline material of the spine and dome yield about 4.5 c. c. of gas (at 1200° 760 mm.) for each gram of lava. The pumice which, while glassy, is fully expanded and may be supposed to have lost most of its initial charge of gas, yields about 1 c. c. more per gram. On the other hand, the glassy crust of the breadcrust bomb yields 26 c. c. of gas per gram, for the most part water, of course. That is to say, the glassy chilled lava retained about four times as much gas as the pumice or the holocrystalline material. The quantity of gas still contained in the chilled glass was therefore about 26 liters for each kilogram of rock, as compared to the 5 or 6 liters which the holocrystalline or pumiceous materials still retain. A similar relation between the gas content of the glassy crust and expanded interior of a breadcrust bomb was observed in examining the Lassen material. It would seem, therefore, that Professor Lacroix may have been in error in supposing that the crust of such a bomb had lost its gas. The glassy crust of such bombs as distinguished from the fritted surface of reheated material is a promising source of volatile matter for study.

In response to numerous inquiries regarding our methods of gas analysis, a detailed description, both of methods of collection and methods of analysis, has been prepared and is now ready for publication. In this paper especial attention has been given to the sources of error in collecting and analyzing these complex mixtures. The analytical complexity becomes apparent when it is remembered that the following possible constituents must be separated and determined: water, carbon dioxide, carbon monoxide, hydrogen, oxygen, nitrogen, methane, sulphur, sulphur di- and tri-oxides, hydrochloric and hydrofluoric acids, the rare gases of the argon group, and sometimes hydrogen sulphide. The apparatus which has been developed, while of considerable complexity, has been proved to be adequate for the purpose.

The study of the volatile ingredients of lavas leads naturally to the examination of the plutonic rocks. For this purpose it is necessary to examine not only the gases still retained in the igneous mass, but also the adjacent sedimentaries for such volatiles as may have been caught and retained by them. An isolated and well-exposed laccolite would seem the ideal exposure for such study. During the summer of 1923 a reconnaissance was made of the better known laccolites in central Montana and southeastern Utah. Much interesting material was obtained with which to test the preliminary hypotheses. The Henry Mountains, while somewhat difficult of access, offer a number of ideal sections for intensive study.

It developed in the course of work on the gases from rocks that a reliable method for the determination of small amounts of fluorine was greatly needed, and this need becomes insistent when contact phenomena are to be studied. Special apparatus has now been developed which permits a satisfactory determination of fluorine as silicon tetrafluoride. There remain to be concluded the experimental details involved in removing the last traces of fluorine from the material under analysis. Traces of fluorine are retained tenaciously, even at high temperatures.

ALUMINA AND SILICA.

Nearly three-fourths of the crust of the earth is composed of silica and alumina, mainly in the form of numerous compounds into which they enter. Such dominance renders imperative an understanding of the mutual relations of silica and alumina at various temperatures as an indispensable first step in any investigation of the rocks of the crust.

In addition to the interest which attaches to alumina and silica from the scientific viewpoint, these oxides and their mixtures are of very considerable importance in the industrial world. All clays are compounded of these oxides, and clay is the great basic raw material of the ceramic industry whose products range from common brick and tile to special wares, such as furnace refractories and again to the finest china. An understanding of the relations of silica and alumina at high temperatures is necessary to the proper treatment of these wares during their manufacture and often during their subsequent use.

Some doubts have gradually developed in our minds regarding the correctness of the accepted ideas regarding the relations between silica and alumina. The doubts arose from observations of the behavior of materials rich in these oxides when they are strongly heated either in furnaces or through contact with molten magma. Further investigation was accordingly undertaken, and the difficulties have now been cleared away.

It has been found that the only compound of alumina and silica which forms at high temperatures is $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$. This observation is quite contrary to accepted opinion which has hitherto regarded $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$, corresponding with natural sillimanite, as the compound stable at high temperatures. A synthetic mixture of the composition of natural sillimanite or, indeed, natural sillimanite itself, far from constituting a maximum on the curve of melting temperatures, actually begins to melt at the comparatively low temperature at 1545°C . Failure of sillimanite wares under load at high temperatures has frequently been observed, and, as it now appears, with sufficient reason.

The compound $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$, on the other hand, melts only when a temperature of 1810° is reached, and the plain inference is that to obtain a highly refractory mixture this 3 : 2 ratio of the oxides must be used and not the 1 : 1 ratio on which so much effort has been expended hitherto.

The melting of the compound $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ at 1810° is accompanied by dissociation and the setting free of alumina as corundum. An explanation thus becomes available of the puzzling formation of corundum in nature at certain rock contacts and likewise in the factory at the contact of molten glass with its clay container.

The results of the investigation therefore offer explanation for many features of the behavior of alumina-silica materials which were matters of

observation both in nature and in the industrial plant. Moreover, we were led to predict that the compound $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ would also be found in nature, and to institute a search for it which met with success in certain rocks from the Island of Mull. These rocks were chosen for investigation on account of the plain evidence from their field relations that they had been subjected to particularly high temperatures, a condition which, as we have seen, is necessary for the formation of $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$. Further search will undoubtedly reveal other rocks which have been formed under similar conditions and which contain this compound. No doubt, in many cases its presence will be the only evidence of the existence of these high-temperature conditions of formation. Thus the petrologist, as the result of finding this compound in a certain rock, will be able to form definite conclusions regarding the conditions of formation of the rock, which is the aim and end of petrology.

ERUPTIVE CARBONATE ROCKS.

Calcium carbonate in the form of limestone, marble, chalk, and in yet other forms, is a very familiar material. Geologists have long studied these various forms and there is general agreement that practically all calcium carbonate is the result of some form of precipitation from aqueous solution. Yet there have not been lacking those who regard certain occurrences of calcium carbonate rocks as a result of consolidation from the molten condition, that is, as eruptive rocks.

Experimental investigation of calcium carbonate shows that it melts as such only under very high pressure and at a temperature of 1339°C . It can be melted at lower temperatures and at lower pressures, but the melt then contains a great excess of CaO over the proportion required for CaCO_3 ; in other words, dissociation occurs. The combination of high pressure and high temperature necessary to melt calcium carbonate without dissociation is not such that we are warranted in expecting it to occur as an igneous rock in that limited depth of the crust of the earth that ever comes under direct observation.

We accordingly looked with some suspicion upon interpretations of carbonate rocks which placed them as eruptive, and finally were led to undertake a field and laboratory investigation of a recently published and widely quoted case, namely, the rocks of the Fen area in Norway, which has led to the conclusion that another interpretation is to be preferred.

In the Fen area there are sideritic and dolomitic carbonate rocks that are generally recognized as formed by replacement of older rocks through infiltrating aqueous solutions. The calcium carbonate rocks are intimately associated with these other carbonate rocks and the relations of the various minerals as seen under the microscope point definitely to a similar origin. The calcium carbonate replaces the minerals of an older rock. Moreover, the general arrangement of the zones of carbonate corresponds with the arrangement which has recently been found to be typical of carbonate replacement.

Thus the recognition of the replacement origin removes the necessity of assuming eruptive calcium carbonate and the apparent discordance between field and laboratory findings disappears.

PUBLICATIONS.

- (512) A note on the crystal structures of lithium iodide and rubidium fluoride. Ralph W. G. Wyckoff and Eugen W. Posnjak. J. Wash. Acad. Sci., 13, 393-397. 1923.

It is shown that the material used in a recent determination (W. P. Davey, Phys. Rev., 21, 143. 1923) of the structure of lithium iodide was in all probability not the anhydrous salt, that the observed intensities of the diffraction lines obtained from this preparation conflict with those calculated for the assigned structure, and that its interatomic distances do not agree with those to be expected from crystals of lithium iodide. This study of lithium iodide is another example of the difficulties that arise from the use of the unaided powder diffraction technique in the determination of the structures of even simple crystals. It is also pointed out that the intensities of the powder lines from rubidium fluoride and the distances between fluorine and rubidium atoms are not in agreement with those to be expected from the structure given at the same time to this crystal.

- (513) Density distribution in the Earth. E. D. Williamson and L. H. Adams. J. Wash. Acad. Sci., 13, 413-428. 1923.

Recent measurements of the compressibility of rocks furnish the starting-point for an estimate of the character of the Earth's interior. Other sources of information which are drawn upon are: (1) the constant of gravitation, from which the total mass and average density of the Earth are determined; (2) the constant of precession and other astronomic and geodetic data from which the moments of inertia of the Earth may be calculated, the moment of inertia allowing important inferences to be drawn concerning the density distribution within the Earth; (3) seismologic data from which the elastic constants of the materials in the interior may be computed.

The high density in the interior of the Earth can not be due to compression alone; but from the fact that a pressure of 1,000,000 megabars is reached at a depth of less than 2,400 km., it is evident that the reduction in volume under such a pressure is a factor not to be neglected. By the use of earthquake data a *quantitative* estimate is given of the density change due to compression of a homogeneous material at various depths—or of that part of the density change due to compression alone in the case of a variable composition. The present distribution, moreover, reconciles the continuity of the velocity depth curves with the difference in velocity in metallic iron and in basic silicate.

The suggested distribution of material within the Earth is as follows: (1) an outer layer 60 km. (about 35 miles) thick in which the material changes more or less gradually from granitic to something more basic than a gabbro; (2) a shell extending to a depth of 1,600 km., consisting of peridotite, that is, mainly of iron-magnesium silicates, and having a normal density 3.3 and a density at 1,600 km. of 4.35; (3) a shell of pallasite reaching to 3,000 km. below the surface, in which silicate rock is gradually replaced by metallic iron (or nickel-iron) not yet completely segregated, the density in this shell changing gradually from 4.35 to 9.5; and (4) below this layer of pallasite a central core of nickel-iron of nearly constant density, varying from a little below to a little above 10.

Of the four zones described, two are sensibly constant in composition, but not of constant density (the central core of nickel-iron and the peridotite shell immediately below the surface layer), and two are of variable composition (the surface layer and the pallasite fringe surrounding the metallic core). The distribution here suggested is at best a rough approximation, but it seems to be the simplest possible arrangement consistent with the physical, seismologic, and astronomic data.

- (514) On babingtonite. H. S. Washington and H. E. Merwin. *Am. Mineralogist*, 8, 215-223. 1923.

New determinations of the chemical and optical properties and of the density of babingtonite have been made. Its unlikeness to the monoclinic pyroxenes has been discussed. The arbitrary character of the boundaries of mineral groups, especially triclinic groups, is mentioned, and it is suggested that babingtonite, rhodonite, pyroxmangite, and sobralite are sufficiently alike and also sufficiently unlike the pyroxenes and other mineral groups, to be grouped by themselves. The unlikeness of babingtonite to acmite is shown also by X-ray spectra taken by R. W. G. Wyckoff.

- (515) The density of the Earth as calculated from the densities of Mauna Kea and Haleakala. Henry S. Washington. *J. Wash. Acad. Sci.*, 13, 453-456. 1923.

E. D. Preston, in connection with latitude and pendulum observations in 1902 at Mauna Kea, calculated the density of the Earth as 5.13, using the densities of specimens collected by him at Mauna Kea and densities of other Hawaiian lavas as given by E. S. Dana. The value is recalculated in the present paper, using a new average density of the Mauna Kea lavas, 2.963, based on determinations made by the author with specimens collected in 1920, that were analyzed for a study of the petrology of the island (cf. No. 491). On this basis the Earth's density is calculated to be 5.245. A similar calculation for the Earth's density, based on the densities of specimens from Halekala on Maui, gives the value 5.877. Preston's equations for the ratios of the average density of the rocks and that of the Earth are assumed to be correct.

- (516) Excavations at Phlius in 1892. Henry S. Washington. *Am. J. Archaeology*, 27, 438-446. 1923.

The excavations, which were confined to the ancient acropolis, were preliminary and were not resumed. The remains of a small temple, with some very unusual details of construction, were laid bare. This is thought to have been the Sanctuary of Ganymeda or Hebe, mentioned by Pausanias. The temple of Hera probably occupied the extreme upper end of the ridge, the temple of Demeter and Kore was probably near a threshold found at the central part, and the temple of Æsculapius almost certainly stood where a chapel of the Virgin now stands and about which many fragments of Doric architecture were found. A square-walled inclosure with columns in its interior, that resembles the sacred inclosure at Eleusis, is identified with the sanctuary of Demeter. Further excavation at the site is recommended.

- (517) Stereoscopic photography in geological field work. F. E. Wright. *J. Wash. Acad. Sci.*, 14, 63-72. 1924.

In geological field work stereoscopic photographs taken by the ordinary roll-film camera are of value in assisting the geologist to revisualize the relations studied in the field. Details which may have escaped his notice are brought out much more effectively than in the single photograph. The taking of stereoscopic photographs for this purpose does not require special apparatus. To obtain good stereoscopic effects it is advisable to take two photographs, one after another and from different positions, of the geological features to be recorded, the distance between the two camera stations to be from 1 to 5 per cent of the distance of the object itself, the camera in each position to be pointed at the object and the lines joining the camera stations to be approximately normal to the lines of sight to the object. The stereoscopic effect can be enhanced if enlarged prints of the negatives are made and a lens stereoscope of the ordinary type is used in the examination of the prints.

- (518) Some new standard melting points at high temperatures. Howard S. Roberts. *Phys. Rev.*, 23, 386-395. 1924.

This paper presents a table of the melting points of pure salts to be used as standard temperatures for the calibration, particularly, of thermo-couples of fine wire (up to 0.6 mm. in diameter). The salts are usually supplied sufficiently pure by the manufacturer, but may be further purified, if necessary, by very simple methods. Their purity need not be checked by analysis, but by noting the character of the melting-point curve, which is also used as a check on the reliability of any particular determination. The salts cover the range 400° to 1100° , with an additional point at 1304° .

- (519) The densities and specific volumes of sodium chloride solutions at 25° . Ralph E. Hall. *J. Wash. Acad. Sci.*, 14, 167-173. 1924.

In connection with some work on the properties of solutions under high pressure, precise values of the density of sodium chloride solutions were required. The available data either did not cover the necessary range of concentration or were not obtained at the desired temperature. The present measurements were made on various concentrations of sodium chloride in water up to 25.5 per cent by weight, and are believed to be accurate to within 5 parts per million.

- (520) The system: $\text{Al}_2\text{O}_3.\text{SiO}_2$. N. L. Bowen and J. W. Greig. *J. Am. Ceram. Soc.*, 7, 238-254. 1924.

Corundum is frequently formed from shales and clays when these are attacked by natural magmas or by artificial melts, such as glasses, even when there is plenty of silica present to form sillimanite. This setting-free of alumina as corundum suggested that sillimanite itself must melt incongruently, breaking up into liquid and corundum. The older work on the system alumina-silica indicated a maximum, congruent melting-point of sillimanite, but this was not as definite as could be desired and a re-examination of the system was therefore undertaken.

The present study has shown that there is only one compound of alumina and silica stable at high temperatures. This compound is chemically distinct from sillimanite, $\text{Al}_2\text{O}_3.\text{SiO}_2$, since it has the composition $3\text{Al}_2\text{O}_3.2\text{SiO}_2$, but its optical and crystallographic properties are very close to those of sillimanite. On account of this similarity of properties the crystals of the $3\text{Al}_2\text{O}_3.2\text{SiO}_2$ compound have been regarded as sillimanite in earlier work.

Since the only compound existing at high temperatures is the 3 : 2 compound, a synthetic mixture of the composition $\text{Al}_2\text{O}_3.\text{SiO}_2$ is always found to be inhomogeneous. As ordinarily obtained, by heating to a temperature of 1600° to 1700° C., it consists of crystals of $3\text{Al}_2\text{O}_3.2\text{SiO}_2$ and a highly siliceous glass.

Natural sillimanite suffers no change when heated for several days at any temperature below 1545° C., the temperature of the eutectic between cristobalite and $3\text{Al}_2\text{O}_3.2\text{SiO}_2$. Above this temperature sillimanite breaks up into crystals of $3\text{Al}_2\text{O}_3.2\text{SiO}_2$ and liquid.

The compound $3\text{Al}_2\text{O}_3.2\text{SiO}_2$ melts incongruently, breaking up at 1810° C. into corundum and liquid. The field of corundum and liquid extends not only beyond the 3 : 2 compound, but also beyond the composition of sillimanite, so that if natural sillimanite or a synthetic mixture of the same composition are heated to a temperature slightly above 1810° C. they form corundum and liquid.

The most refractory mixture of alumina and silica is not the 1 : 1 mixture as has been supposed hitherto, for such a mixture begins to show some formation of liquid at 1545° . A mixture of the composition $3\text{Al}_2\text{O}_3.2\text{SiO}_2$ is much more refractory, since it begins to melt only at 1810° C.

The crystals of so-called sillimanite occurring in various kinds of ceramic wares are always crystals of the $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ compound. In the presence of much Fe_2O_3 and TiO_2 the crystals may take these oxides into solid solution and their properties may then be changed in such a way that they are indistinguishable from sillimanite except by chemical analysis. Fortunately, in the vast majority of wares the amount of iron and titanium is small and the crystals of $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ are readily identifiable as such by optical means alone.

- (521) The year's progress in volcanology. Arthur L. Day. Bull. National Research Council No. 41 (vol. 7, part 5), pp. 71-73. 1924.

Report at the annual meeting of the American Geophysical Union in April 1923.

- (522) Status and problems of geophysical chemistry. Robert B. Sosman. Bull. National Research Council No. 41 (vol. 7, part 5), pp. 74-77. 1924.

Report at the annual meeting of the American Geophysical Union in April 1923.

- (523) Mullite, a silicate of alumina. N. L. Bowen, J. W. Greig, and E. G. Zies. J. Wash. Acad. Sci., 14, 183-191. 1924.

Having found, in the course of an investigation of the system alumina-silica, that $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ is the only compound stable at high temperatures, we anticipated that this compound would be found in rocks of the appropriate composition when formed at high temperatures. We therefore examined some sillimanite buchites, so-called, from the Island of Mull, kindly supplied us by Dr. H. H. Thomas, and found that the "sillimanite" is really the $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ compound, for which we accordingly propose the name *mullite*.

The optical properties of pure mullite have been determined, as well as those of a series of mullites of varying TiO_2 and Fe_2O_3 content mounting to about 4 per cent. The properties show a remarkable similarity with those of sillimanite, the members of the series highest in $\text{TiO}_2 + \text{Fe}_2\text{O}_3$ being practically indistinguishable from sillimanite in optical properties. Chemically, however, the two compounds, mullite and sillimanite, are always distinct, and in spite of their crystallographic similarity there is no solid solution series between them. Mullite will, no doubt, be found in other rocks. Its presence in some rocks and that of sillimanite in others will afford useful information regarding the relative temperatures of formation of the rocks.

- (524) The lavas of Barren Island and Narcondam. Henry S. Washington. Am. J. Sci., 7, 441-456. 1924.

These two small, wholly volcanic islands are situated east of the Andamans in the eastern part of the Bay of Bengal. Barren Island consists of a somma ring, with an active cone, 309 meters high, in the center of the caldera. It was in violent eruption in 1789, when the island was first visited, and since then has been in an almost continuous state of solfataric activity. The lavas of Barren Island are dominantly pyroxene andesite, with some olivine-free labradorite basalt. Four chemical analyses are given of these rocks. Narcondam is extinct and shows no signs of a crater. It rises to a height of 713 meters and its slopes are deeply eroded. It is apparently older than Barren Island. The rocks of Narcondam seem to be uniformly hornblende dacite, of which two analyses are given. The relations of the two islands to the "Malay arc" are discussed.

- (525) A superior electric pendulum; and some pendulum equations. W. P. White. J. Opt. Soc. Amer., 8, 767-782. 1924.

Attention is called to the great ease with which a very accurate clock pendulum of the electric-gravity type can be built. Simple equations are

given showing how the design may be ordered to diminish the recognized errors inherent in the method of driving. These equations are used to discuss the value of this and other types of drive for pendulums of maximum accuracy, and indicate that the electric-gravity drive equals, and possibly excels, the best of other types for such service.

(526) The Fen area in Telemark, Norway. N. L. Bowen. *Am. J. Sci.*, 8, 1-11, pls. I-III. 1924.

A small intrusive plug of alkaline rocks at F  n, Norway, has certain carbonate rocks associated with it that have been interpreted by Br  gger as intrusive.

Re-examination of these rocks has led to the alternative explanation that the carbonates have been introduced by replacement of igneous rocks already solidified. The carbonate replacement has followed a course which Hewett has shown to be typical of such action in a number of examples. The successive zones of siderite, dolomite, and calcite, to be expected in Hewett's scheme, are well illustrated in the area, and the detailed relations of the carbonates to the other minerals show that the carbonates have been introduced subsequent to the consolidation of the rock.

These observations render unnecessary the assumption that a mass of limestone has been melted in depth and injected into the rocks of the Fen area after the manner of an eruptive rock.

(527) A new autocollimator. F. E. Wright. *J. Opt. Soc. Amer.*, 9, 187-188. 1924.

In this autocollimator, which is essentially a telescope system, the optical parts are so arranged that the field of view is divided into halves, as in a range-finder of the self-contained type. In the left half of the field a bright fine line is imaged and indicates the position of the reflecting surface under test; in the right half a fine bright line of reference and an illuminated scale are visible; the scale is so divided that from it the angular departure of the reflecting surface from exact autocollimation can be read off directly. Experience has shown that with the two fields thus placed side by side in contact the accuracy of a single setting is about five times that obtainable with two superimposed fields, as in the Gauss method of autocollimation.

(528) (Review of Goodchild's and Campbell's theoretical papers on ore deposits.) Robert B. Sosman. *Econ. Geol.*, 19, 585-589. 1924.

A paper by W. H. Goodchild on *The Evolution of Ore Deposits from Igneous Magmas* and one by J. M. Campbell on *The Genesis of Igneous Ore Deposits* have been much discussed in Great Britain and are held to be fairly representative of current thought on this general subject among British mining geologists. This critical review shows that the papers represent a distinct advance in the recognition that the problems of ore deposits are problems in physical chemistry; but the review also shows that the theories are not well established on the experimental data now available.

(529) The composition of the earth's crust. Frank Wigglesworth Clarke and Henry S. Washington. *U. S. Geol. Survey Prof. Paper No. 127*, v+117 pp. 1924.

This paper discusses fully and in detail the chemical characters of the earth's crust. In an introduction are discussed briefly the interior of the earth and the general mineral and chemical characters of igneous rocks. In the next section are presented some 50 averages of the chemical composition of the igneous rocks of various countries and the several continents and other divisions of the earth, concluding with a final statement of the average chemical composition of the igneous rocks of the earth's crust (assumed to be about

10 miles deep), with estimates of the relative abundance of the rare elements. The calculated average composition of the sedimentary rocks is also given and the average composition of the crust, including igneous rocks, sedimentary rocks, the hydrosphere, and the atmosphere. These averages are based on the collection of igneous rocks published by one of the writers in 1917 (*Chemical Analyses of Igneous Rocks, published from 1884 to 1913, inclusive, with a Critical Discussion of the Character and Use of Analyses*, by Henry S. Washington, U. S. Geol. Survey Prof. Paper No. 99). The various methods of obtaining trustworthy averages are described and the analytical data regarding the occurrence of many of the rare elements are also presented. A section deals with the relations of analytical methods and the errors involved in the determination of the various constituents. In another section are discussed the general chemical character and representativeness of the various areal averages, pointing out in how far they may conform with the true state of affairs.

The association and distribution of the elements are dealt with in another section. It is shown that the chemical elements may be referred to two large groups, the petrogenic and the metallogenic; the former being most abundant in and specially characteristic of igneous rocks, while the latter are found almost wholly in ores. In this section the relations of each of the elements to the others, as shown by their mineral associations, are discussed in great detail. Minor types, the spectroscopic differences between the elements, and the elements that make up meteorites are also treated briefly. There is also a somewhat detailed statement of the so-called correlation of the elements, that is, the selective tendency which they severally show toward association with igneous rocks of particular dominant chemical characters.

In a final section the evolution of the elements is discussed; it being suggested that the elements have undergone evolution from the few primordial elements (hydrogen and helium) of the nebulae through the more numerous elements of the sun and stars to the complex compounds, such as are found on the earth.

(530) Annual Report for this year.

(531) to (538) inclusive. These eight papers form the Laboratory's contribution to a "Symposium and discussion on the temperatures of hot springs and the sources of their heat and water supply," held under the auspices of the Sections of Volcanology and Geophysical Chemistry of the American Geophysical Union at its annual meeting in April 1923. Individual abstracts follow.

(531) The source of the heat and the source of the water in the hot springs of the Lassen National Park. Arthur L. Day and E. T. Allen. *J. Geol.*, 32, 178-190. 1924.

As a result of the investigation, the conclusion is reached that the hot springs are fed chiefly by surface-water which drains the basins in which they lie, and that the variation in the volume of this water locally and seasonally accounts for the variations in volume and for the greater part of the variations in temperature which are found in the springs. Another portion of water, probably much smaller in amount, is believed to be derived from an underlying magma or batholith. Rising in the form of steam along with other volcanic gases through clefts in the rock, it is condensed by the ground-waters and becomes mingled with them. The proportion of this magmatic water varies in different springs and at different times in the same spring, not so much because of inconstancy in the emanation as because of variations in the volume of ground-water.

Some of the heat, perhaps a large part of it, is derived from the magmatic steam. Another portion conveyed by conduction through the lower depths

of the rock is carried through the upper strata by the evaporation of a fraction of the ground-water in a manner which is explained in the paper.

Whether the spring waters descend throughout their whole course, or whether they ascend in the latter part of it as artesian waters do, has not been ascertained, but the evidence indicates that the *liquid* water comes from no greater depth than the ground-water penetrates, and the mineral-content of the waters, excepting the volatile portions or portions which were at one time volatile, is all derived from the rock above that level.

(532) A physical source of heat in springs. Leason H. Adams. J. Geol., 32, 191-194. 1924.

This paper calls attention to a source of heat which appears not to have been considered in previous discussions of the origin and phenomena of hot springs, namely, the rise of temperature accompanying the forced flow of a liquid from a region of high pressure to one of low pressure. For example, the expansion of water through a valve or orifice from a constant pressure of 4,000 megabars (about 4,000 atmospheres) down to 1 megabar will raise it from room-temperature to the boiling-point. Comparatively small effects are to be expected in *meteoric* water, because the pressures are usually not high, but the temperature rise in *magmatic* water, released under rock pressures, might be considerable.

(533) Relation of crystallization to the water content and vapor pressure of water in a cooling magma. George W. Morey. J. Geol., 32, 291-295. 1924.

The entire cooling of an igneous magma, from the initial condition in which the magma consists essentially of non-volatile substances, with but a small amount of water, to the dilute solutions given off by hot springs, is a continuous process. If the magma is cooling under a competent crust, the non-volatile substances crystallize from a liquid containing more and more water, and at all times in the process there is a liquid phase. The liquid exerts over the entire range of cooling a vapor pressure which at first increases rapidly to a maximum, then decreases, and at all times the vapor pressure is not that of water at the temperature in question, but of an aqueous solution in which the vapor pressure of the water is much reduced by the dissolved material. In natural magmas critical phenomena probably play no part.

(534) Hot springs of the Valley of Ten Thousand Smokes. E. G. Zies. J. Geol., 32, 303-310. 1924.

The chief constituent of the gases escaping from the fumaroles is water, which is present to the extent of about 99.9 per cent. The temperatures ranged from 100° to 645° C. when first measured in 1917, but the activity seems to be waning and the temperature at any given outlet has been declining. A few hot springs appeared in 1919.

Evidence is brought forward that an important factor in this decline is the large amount of water draining into the Valley from surrounding regions and being absorbed by the pumice flow which makes the present floor of the Valley. The amount of water appearing as steam is not less than 5,700 cubic meters per hour and may be as much as 58,000 cubic meters per hour. The vaporization of this water carries off an immense amount of heat from the unseen supply beneath the Valley.

It is evident that at some time in the near future the present thermal activity of the Valley of Ten Thousand Smokes will resolve itself into that of a hot-spring area. Considerable interest is thus attached to the changes that will take place in the progression from an intensely hot fumarolic area to that condition in which hot springs are the dominant thermal activity.

Equally interesting, on account of the many economic minerals found in the incrustations, are the mineralogical changes which must of necessity take place as the temperature of the region grows less. For this reason alone the Valley is worthy of additional study.

- (535) Hot springs and fumaroles of "The Geysers" region, California. Arthur L. Day. *J. Geol.*, 32, 459-460. 1924.

Brief preliminary notes on this fumarole region, which is now (1924) being investigated in greater detail.

- (536) Notes on the solfatara of Sousaki (Greece), a recent eruption of Methana, and recent maccalube at Vulcano. Henry S. Washington. *J. Geol.*, 32, 460-462. 1924.

The solfatara of Sousaki is of interest because it is apparently at the northern extremity of the line of Aegean volcanoes, including Methana, Aegina, Milos, Santorini, and Nisyros. Methana appears to have been in eruption in 1922, after a quiescent period of about 2,170 years, the longest recorded period of repose between outbreaks of any known volcano.

Newly formed maccalube or boiling mud-pits were observed at Vulcano in 1922. Their temperatures are 95° to 100° C. The hot water and gas rise both on land and under the sea.

- (537) The hot springs of Iceland. F. E. Wright. *J. Geol.*, 32, 462-464. 1924.

A brief outline of the general features of this interesting hot-spring region. The period of reconnaissance work on these springs and geysers has now passed, and detailed quantitative measurements are essential to further progress in our knowledge.

- (538) Notes on the discussion of the papers presented in the Symposium on Hot Springs. Robert B. Sosman. *J. Geol.*, 32, 464-468. General summary of the Symposium on Hot Springs. *Ibid.*, 468-471. 1924.

The principal points covered by the discussion are: (1) The amounts of water available from magmas; (2) the effect of forced flow in low-temperature springs; (3) the age of hot springs now active; (4) the transfer of heat by convection; (5) the production of heat by flow of steam from high to low pressures; (6) distribution of hot springs in the United States.

The summary brings out the general agreement that the principal source of heat for hot springs is in subcrustal rock magmas. Chemical reactions, forced flow, and heat conducted normally from the interior are accessory sources. The mode of transfer of the heat from the magma to the hot spring is still in doubt, with the preponderance of evidence favoring the view that escaping magmatic water carries the heat upward. Auxiliary convective circulation may also aid. The source of the water is also in controversy, with the preponderance of evidence favoring the view that in regions of great visible activity, such as Iceland and the Yellowstone, the main supply is meteoric, while small hot springs of continuous flow may well be of magmatic origin. The symposium emphasizes the need for continuous detailed observations in selected areas, to follow up our present rather widely scattered qualitative information.

DEPARTMENT OF HISTORICAL RESEARCH.

J. FRANKLIN JAMESON, DIRECTOR.

Under a new plan, made applicable to all the Departments of the Institution, the following report, the nineteenth annual report submitted by the present Director, is to bring its record of operations to an end with the date of June 30, 1924; it therefore covers a period of only 10 months, extending from September 1, 1923, to the date named. During these 10 months no changes have occurred in the staff of the Department. Mr. Leland has been in Paris throughout the 10 months, with a few exceptions. The chief of these exceptions arose from his appointment to give, during the past winter, the lectures at the various French universities called the Harvard Lectures, founded by Mr. James Hazen Hyde. These entailed a tour of all the French provincial universities, and the giving, at each, of a public lecture and of a less formal address to and conference with professors and students. The subject chosen was that of French colonization in America, one of the chief fields of Mr. Leland's work in Paris, and one in which he desired to encourage interest among French historical scholars. He also spent a short time in Brussels in May, on occasion of the meetings of the Union Académique Internationale and the International Committee of Historical Sciences, of whose provisional or special committee he is the American representative and the secretary. At the end of June he came back to the United States, the American Council of Learned Societies having, by arrangement with the Carnegie Institution, engaged his services for the second half of 1924 in the prosecution of work which the Carnegie Corporation has asked it to undertake. Miss Griffin spent the month of October in Albany, in connection with work described later in this report.

By action of the trustees, Professor Samuel F. Bemis, hitherto professor of history in Whitman College, hereafter professor in the George Washington University, was appointed Fellow of the Carnegie Institution of Washington for the year beginning September 1, 1923. From September till May, Mr. Bemis was closely associated with the Department, to its great pleasure and profit, though not required to take any part in its regular or usual work. He occupied himself in interesting and valuable researches of his own, conducted in the archives of the Department of State and in the Library of Congress, relating to the diplomatic history of the United States during the period from 1776 to 1800. For further prosecution of the history of diplomatic negotiations with Spain, Mr. Bemis went to Madrid in May, and was working profitably in the archives there at the time at which the present report concludes. The year's labors, supplementing those already manifested in Mr. Bemis's book on *Jay's Treaty*, are intended to pave the way toward an extended work on the diplomatic history of the United States.

Several persons outside the regular staff of the Department have during the year given valuable assistance to its work. Professor John S. Bassett, of Smith College, continued throughout the year, at various times, his editorial work upon the Correspondence of Andrew Jackson. Mrs. R. C. H. Catterall, of New York City, continued in the prosecution of her part of our work during most of the 10 months. Mrs. N. M. Miller Surrey, of New York City, continued her work at its usual rate till February, when it was, in a sense, com-

plete, and since then has from time to time given various hours to certain processes of revision. Miss Elizabeth Donnan, associate professor in Wellesley College, Professor Marcus W. Jernegan, of the University of Chicago, and Miss Elizabeth Waterston, of that institution, gave some aid in the same lines as in the preceding year. Others outside of our regular staff who assisted in the work of the Department during the year were Mr. Abel Doysié, of Paris, Miss Ruth A. Fisher of London, and Miss Irene A. Wright of Seville.

Acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, as in previous years, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, librarian; by Mr. A. P. C. Griffin, chief assistant librarian; by Mr. Charles Moore, chief of the Division of Manuscripts; and by Mr. John C. Fitzpatrick of that division. Grateful recognition is also made of the courtesies shown by the New York Public Library in facilitating the work of Mrs. Surrey; by the library of Harvard University in aiding that of Miss Davenport; by the Association of the Bar of New York City in affording to Mrs. Catterall special opportunities for her work; and by the authorities of the British Museum, the Public Record Office in London, and the libraries and archives of Paris.

REPORTS, AIDS, AND GUIDES.

Mr. Leland, with the aid of Mr. Doysié, pushed forward nearly to its completion, during the 10 months reported upon, the preparation of the first volume of his *Guide to Materials for American History in Paris Archives and Libraries*. That first volume is to be devoted to materials in libraries. The work done during these months lay mainly in the Bibliothèque Nationale, where Mr. Doysié took notes of materials for American History in the "Nouvelles Acquisitions," Mr. Leland in a large number of earlier volumes of manuscript. The work was interrupted in the middle of June by Mr. Leland's return to the United States, for purposes above mentioned, but some of it will be continued by Mr. Doysié during the remainder of the year, and the rest resumed by Mr. Leland in 1925.

Mrs. Surrey's *Calendar of Documents in Paris Archives relating to the History of the Mississippi Valley* was practically completed by the middle of the period reported upon. The work done up to that time consisted in the editing of material represented by transcripts in the Library of Congress, material derived from Series C¹¹ of the Archives des Colonies, and material from the archives of the Ministry of War; and in revision of the mass of cards composing the *Calendar*. The completion of the chronological arrangement resulted in the consolidation of duplicate entries, representing copies of the same document, to such an extent as to reduce the total number of cards, beyond the reduction mentioned last year, by more than 1,200 further numbers. The *Calendar* must now await further revision, which Mr. Leland desires to give to it in 1925.

Going to Albany about the first of October, Miss Griffin spent a month in assisting Mr. A. J. F. van Laer, archivist of the State of New York, in the work of preparing for publication his report on the materials for American history in the archives of the Netherlands. Mr. van Laer took copious notes upon these numerous and important materials during an expedition made to the Netherlands at the instance of the Department in the spring of 1919, but had not been able since then to prepare his formal report. Some progress in

this endeavor was made, by these joint efforts, during the month of October, but it does not appear that Mr. van Laer has been able to make much further progress since that time.

With respect to the contemplated *Guide to the Materials for American History in Scandinavian Archives*, the chief results to be reported are those obtained by Mr. Gunnar J. Malmin, who, as stated in last year's report, sailed for Scandinavia in July 1923, as holder of a fellowship awarded for the purpose by the American-Scandinavian Foundation. At the date at which last year's report ended, Mr. Malmin had nearly completed his search for material respecting emigration in the archives of the Social Department and the other executive departments in Christiania. Subsequently he completed his Norwegian researches by work in the Staatsarkiver in Christiania, Bergen, Hamar, and Trondhjem and in the police archives of the chief Norwegian cities. He also made a special search for what are called "America letters," and found a considerable number. The most interesting result of his searches in Norway was, however, the discovery of an important group of materials in the archives of the Society of Friends in Stavanger, from which port the first body of Norwegian emigrants, mostly Quakers, whose position in the ecclesiastical system of Norway had become uncomfortable, sailed for America in 1825. In his searches in this archive he received important and very kindly assistance from Mr. Thorstein Bryne, of the Stavanger Friends Meeting. The discovery of an official report made in 1836 by the *amtmand* in Stavanger definitely connected this earlier and sporadic instance of emigration in 1825 with the continuous movement of emigration to America which began in 1836.

Mr. Malmin's efforts in Sweden were aided with every courtesy by officials, but it appeared that almost no material respecting emigration was to be found in manuscript, additional to the copious materials which are to be found printed in Professor G. Sundbärg's *Emigrationsutredning*. At Upsala, where, as in Stockholm, all sources respecting the Swedish settlements on the Delaware seem to have been exhausted by Professor Amandus Johnson, Mr. Malmin found material on the Bishop's Hill Colony in Illinois, recently acquired in the Fröken Anna Lindewalls Samling. He also visited the archives of Gothenburg, Malmö, and Lund.

In Denmark, in whose archives little information respecting emigration to America is to be found, Mr. Malmin also undertook to prepare a report on the papers in Danish archives concerning diplomatic relations between the United States and that country. In this effort he was kindly assisted by the American minister, Dr. John Dyneley Prince, by Count Reventlow, Minister of Foreign Affairs, and by the archivist of the foreign department, Mr. Axel Heils. He was permitted to take notes of all correspondence in the archives down to 1850, and of lists of documents for a considerable period after that date.

At the end of June, Mr. Malmin returned to the United States. Large portions of his report had been received before that date. When the remainder has been received it will be possible, by combining it with Mr. Eric Naumann's account of the diplomatic papers concerning America in the Swedish archives, the notes of Mr. Amandus Johnson respecting New Sweden, and those of Professor Waldemar Westergaard on the papers in Copenhagen respecting the Danish West Indies, to form a satisfactory guide to all materials for American

history that are to be found in any but parochial and other local archives in the three Scandinavian kingdoms.

It was mentioned in the last report that that book of the Department which is to treat, in natural combination, of the archives of the British West Indies and of the West Indian section of the Colonial Office Papers preserved in the Public Record Office in London, would wait for its completion until it had been possible to carry out the examination of the archives of those Lesser Antilles which are colonies of Great Britain. The Department already has excellent reports on the archives of Bermuda, the Bahamas, and Jamaica, and on the West Indian "classes" in the Colonial Office Papers. During the year arrangements have been concerted by which Mr. David W. Parker, formerly a member of the staff of the Department, and then for some 12 years keeper of the manuscript room in the Public Archives of Canada, should in September 1924, proceed (from Europe) to Trinidad, and thence up the chain of British islands to Antigua, and thus spend the last 3 months of the year in the careful exploitation of the island archives for the purposes of the Department's proposed volume.

The work of Dr. Paullin upon the *Atlas of the Historical Geography of the United States* has advanced during the year in three particulars. First, he has completed all the maps relating to military history, illustrating campaigns and battles of the Revolution, of the War of 1812, of the Mexican War, of the Civil War, and of the American participation in the World War, and illustrating American naval warfare. Secondly, he has completed 24 maps illustrating the progress of several important movements of reform—the movement for the abolition of slavery, the movement for the abolition of property qualifications for the suffrage, that for woman's suffrage, and that for prohibition. For all maps that have been completed, the letterpress has also been prepared. Dr. Paullin has also made preliminary maps, based on the United States censuses, illustrating the density of population at dates from 1790 to 1920. In the execution of the maps he has, as usual, had the aid of Mr. J. B. Bronson as draftsman.

The last annual report described fully the volume prepared by Mr. David M. Matteson of Cambridge, entitled, *List of Manuscripts concerning American History preserved in European Libraries and noted in their Published Catalogues and Similar Printed Lists*. At the beginning of the 10 months now reported upon, the manuscript of this volume was in the hands of the Department. Editorial revision by the Director, the making of some additions, and final preparation for the press brought it about that the manuscript was not sent to the printer until May 1924. The volume may be expected to appear by the end of the year. Of the additions spoken of, the principal ones consisted of supplementary items from the more recent catalogues of manuscripts in the British Museum; for, while in general the book omits details respecting manuscripts concerning American history in London libraries, because they have been covered already in Andrews and Davenport's *Guide to the Materials for American History in the British Museum*, etc., and in others of the Department's British Guides, the latest of these volumes, published in 1914, carries the description of manuscripts in the British Museum no farther than the acquisitions of the year 1910.

Catalogues since published by the trustees of the British Museum contain indications of a considerable number of additional manuscripts relating to

American history. It has therefore seemed expedient to include these later additions in the present volume. Manuscripts concerning American history in Oxford, Cambridge, and Rome are left to be known from Andrews and Davenport's *Guide*, and from Professor Fish's *Guide to the Materials for American History in Roman and other Italian Archives*, while those in the libraries of Paris will be fully covered by the volume which Mr. Leland is preparing. The volume now in the press will make nearly 250 pages of print, listing some 2,000 different manuscripts, for the most part unknown to American investigators. It will be provided with a careful index.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

The second volume of Miss Davenport's *European Treaties bearing on the History of the United States* has been advanced by the completing of work upon the American portions of four treaties—the Treaty of Ryswick, 1697, the partition treaties of 1698 and 1700, and the Spanish-Portuguese treaty of alliance of 1701.

The third volume of Dr. Burnett's *Letters of Members of the Continental Congress* will extend from January 1, 1778, to June 30, 1779. During the period reported upon, additions to the texts already accumulated were made, through the courtesy of Mr. Worthington C. Ford, of the Massachusetts Historical Society, in supplying from the Warren collection new letters of Samuel Adams to James Warren, and through that of Mr. Otis G. Hammond, of the New Hampshire Historical Society, in furnishing letters from the papers of Meshech Weare, recently acquired by that society. Other additions to the texts come from the diaries of John Fell and Samuel Holten, not previously exploited. The other work of the year has consisted in the making and revising of annotations to this third volume, which is now approaching completion.

In March, the Institution published the first volume of the *Proceedings and Debates of the British Parliaments respecting North America*, edited by Dr. Stock, a volume of 535 pages, extending to the year 1689, and replete with material for American history which, it can be fairly stated, has hitherto been very little known to American historians. The volume contains all records of proceedings in the English Parliaments relating to America from 1542 to 1689, in the Parliaments and Conventions of the Estates of Scotland, and in the Parliaments of Ireland, down to the same date, and all notes of debates of that period and on that subject which it has been found possible to obtain from printed books or from manuscripts in England.

Since its completion, Dr. Stock has occupied himself with the further prosecution of work upon his second volume, which is likely to extend to 1714. Most of its texts have long been ready; its annotation has been completed up to the end of the year 1695. The most interesting matters dealt with in the portions thus far completed have been the affair of Jacob Leisler in New York, and the episode of the Darien Company. New debate material respecting the affair of Captain William Kidd has been found in one of Lord Hardwicke's volumes in the New York Public Library.

Miss Donnan, whose duties as an associate professor in Wellesley College leave her but a minor portion of time for the completion of the work on which she was engaged when she resigned from the staff of the Institution, has been able, since her work last summer, to carry a little farther the preparation of her volumes of documents illustrative of the history of the African slave trade

to the United States, especially in respect to Rhode Island and South Carolina. Some additional transcripts from the papers of the Royal African Company in London have been received from Miss Fisher, and a larger quantity has been supplied from the archives of the Indies in Seville by Miss Irene A. Wright of that city.

The work of Mrs. Catterall, in drawing off from the American judicial reports the materials occurring in cases respecting slavery and the negro, has been continued by bringing nearly to its end the examination of the Federal reports. She has also prepared her introduction to the Virginia cases (the text of which was completed in a previous year), exhibiting the development of Virginia law respecting Indian and negro slavery, especially in the seventeenth century. A by-product of her work, an account of some antecedents of the Dred Scott case found in Missouri reports, was read at the Columbus meeting of the American Historical Association in December, and is to be printed in the October 1924, number of the *American Historical Review*. Nearly everything necessary to the first volume of Mrs. Catterall's compilation is now finished, together with some portions of the second volume.

Professor Bassett has nearly finished his editing of the *Correspondence of Andrew Jackson*.

Some very slight additions of material for the proposed volumes of the *Correspondence of British Ministers to the United States* have been received during the year. All the material that there is any likelihood of obtaining for the first two or three volumes is now in hand. The real obstacle to progress toward their publication is simply the inability of the Director of the Department to find the necessary time, along with the other duties belonging to his office, for the work of annotating and otherwise preparing these interesting and important letters for the press. He has, however, made some progress in that work, upon the first volume, which will be devoted to the correspondence of George Hammond, British minister in Philadelphia from 1791 to 1795.

In October, the Institution published the first volume of the four which will constitute the series entitled, *Historical Documents relating to New Mexico, Nueva Vizcaya, and the Approaches Thereto*, collected by the late Dr. Adolph Bandelier and Mrs. Bandelier, and edited by Professor Charles W. Hackett, of the University of Texas. It is a volume of 522 pages, containing 92 documents, almost all of them quite unknown hitherto, derived chiefly from the Archives of the Indies in Seville. The Spanish texts and careful translations into English are given on opposite pages, and elaborate introductions by Dr. Hackett, with such annotations as are necessary, explain the documents and their bearing and importance. The documents include a body of sixteenth-century reports relating to the services and merits of explorers and conquerors of New Spain, *cédulas* and letters relating to Indian affairs in the region indicated in the title of the volume, documents relating to the colonial administration of New Spain, and an especially important body of documents relating to the founding of New Mexico and the contending efforts in that direction by Don Juan de Oñate and Don Pedro Ponce de Leon. It is not too much to say that the early history of New Mexico is to be largely rewritten in the light of these documents. Much of the work of editing the second volume of this series had been done before the end of the period now reported upon, but the ensuing summer was relied upon for the completion of the task.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff, mainly by the Director and Miss Griffin, with aid from Dr. Burnett in one section. Various help has been given to the American Historical Association and other historical societies, especially in respect to investigations in Washington archives, and many inquiries from historical students have been answered or transcripts of documents procured for them.

The Director has served as one of the two representatives of the American Historical Association in the American Council of Learned Societies, and as chairman of its committee on a proposed dictionary of American biography, similar in design to the British *Dictionary of National Biography*. Mr. Leland has rendered important service in the organization of the International Committee of Historical Sciences provided for by the International Historical Congress held in Brussels in April 1923. He has by invitation attended sessions and assisted in the work of one of the subcommittees of the Committee on Intellectual Cooperation organized by the League of Nations, and has continued to direct the work of transcribing documents in Paris archives for the Library of Congress. His lectures in the French provincial universities have already been mentioned. Dr. Stock has given a course of historical instruction in the Catholic University of America, and a course of lectures at the Catholic Summer School of America at Cliff Haven, New York.

DEPARTMENT OF MERIDIAN ASTROMETRY.¹

BENJAMIN BOSS, DIRECTOR.

In presenting the report of the Department of Meridian Astrometry it is well to observe that there seems to be a highly disproportionate part devoted to studies outside the scope of the project proper. This, however, does not represent the proportion of effort devoted to each. On the contrary, the time devoted to each project is more nearly inversely proportional to the square or the cube of the space devoted to it in the report. The cause is easy to find. Whereas the outside studies lead to results in a short space of time, each investigation requiring space in the report, the main project involves literally hundreds of thousands of operations each year which can be described in a few sentences.

Progress on the main project has been very satisfactory during the past year. While it has taken longer than was anticipated to collect the San Luis observations and to run down the outstanding errors, the Albany observations are further advanced than was anticipated.

REDUCTIONS OF OBSERVATIONS.

In the process of assembling the observations taken at the San Luis station, much remained to be done to eliminate both ordinary and unusual errors found through comparisons. Various checks have been applied and large numbers of unusual discordances have been investigated. Besides duplicating the computations of precessions and secular variations, and verifying transcriptions, comparisons have been made with the expansion sheets of the General Catalogue to discover gross errors. Several series of observations were revised for azimuth and clock corrections. The formation of the catalogue of 15,333 stars is now complete and the checking of the copy is well advanced preparatory to the formation of a typed copy which will be photographed for reproduction in the publication.

Continued progress has been made in reducing the Albany zenith distances. The circumpolar observations have been discussed to determine the general refraction correction and peculiarities of each observer, and the fundamental system has been modified to fit the instrument and each observer, that consistent equator-points might be derived from stars of different declinations. The derivations of the equator-point, with its rate—sometimes variable, but usually uniform—and of the refraction factor for each individual series of observations have been completed. It is expected that these will be the final values, except for series showing the need of exceptional treatment. The indicated corrections have largely been entered on the computation sheets, the summations are well advanced, and the derivation of the declinations is so well advanced that a beginning has been made in collating the observations preparatory to deriving the final corrections to reduce the observations of the individual observers to the mean of all, and to form a homogeneous catalogue of all the observations.

The final azimuth and clock corrections of the Albany observations have been determined for all the strictly fundamental series, as well as for about 60 semi-fundamental series. The corrections in right-ascension depending upon

¹ Address: Dudley Observatory, Albany, N. Y.

right-ascension and declination have been derived. The diurnal term has, likewise, been computed for these series. For the miscellaneous series of observations, preliminary values of the azimuth correction have been determined for the purpose of forming the clock corrections.

STELLAR PARALLAX.

An attempt has been made to derive corrections to parallaxes based on a method as free as possible from objectionable features, as the method outlined in the last report is subject to a class of error difficult to remove.

The most promising method, perhaps, requires a mean parallax formula. This has been derived from the observed trigonometric parallaxes grouped according to proper-motion. It gives a relationship between mean parallax on the one hand and proper-motion and visual magnitude on the other. Median parallaxes were actually determined, as they more closely represent the average parallax. The formula thus determined was compared with the different series of parallax observations to determine their systematic errors. The following corrections were obtained: Allegheny, $+0''.0010$; Greenwich, $+0''.0030$; McCormick, $+0''.0004$; Mount Wilson, $-0''.0018$; Sproul, $-0''.0072$; and Yerkes, $+0''.0011$. These results are in fair agreement with previous determinations, though the tendency in most cases is to decrease the size of the corrections.

Corrections were deduced, also, for the series of 1,646 spectroscopic parallaxes observed at Mount Wilson. These parallaxes were largely based on the trigonometric parallaxes available at the time the spectroscopic system was devised, and will necessarily need modification with the accumulation of more data upon which to base them. It was found that for stars of small proper-motion the Mount Wilson spectroscopic parallaxes require a very considerable correction, in the direction of decreasing the observed parallaxes. For proper-motions about $0''.042$ it becomes zero and, from that point until proper-motions of about $0''.25$ are reached, a positive correction is needed. For larger proper-motions there is essential agreement between the formula and the spectroscopic parallaxes.

The curve representing the corrections to the spectroscopic parallaxes of 544 stars of A-type determined at Mount Wilson is somewhat similar to that representing the corrections to the spectroscopic parallaxes of the later-type stars, but is displaced in the sense of giving a greater negative correction to the parallaxes of stars of small proper-motion.

In the process of investigating the corrections to the spectroscopic A-type parallaxes, comparison was made with the mean parallax derived from both the trigonometric parallaxes and from proper-motions. The interesting fact developed that the two systems of mean parallax disagreed systematically. The mean parallaxes for stars of small proper-motion as derived from proper-motions seem to be smaller than those derived from the trigonometric parallaxes, while for stars of large proper-motion the reverse is true. The difference may be due, wholly or in part, to the method employed, which will require further investigation with additional data.

PROPER-MOTIONS OF THE CLASS O STARS.

Considerable interest attaches to studies of the motions of the Class O stars, as they afford a promising test of Eddington's theory that stellar luminosity is a direct function of mass. Not only are they probably, as a class,

the most massive of all the stars, but also their dispersion in mass greatly exceeds that of any other class. From a study of the proper-motions of 84 and the radial velocities of 49 of these stars Wilson has shown that, statistically considered, the dispersion in distance about a mean represented by a parallax $\pi = 0''.0013$ is relatively small and that, therefore, there must exist among them a considerable dispersion in absolute magnitude, in direct contrast to what should be expected on the basis of the giant-dwarf theory of stellar evolution. This range in luminosity can not be wholly explained as the effect of errors, either systematic or accidental, in the proper-motions, but may be reasonably explained on the theory that absolute magnitude is a direct function of mass. If this is the true explanation of the apparent dispersion in luminosity, the parallaxes of the individual stars computed on the basis of a mean absolute magnitude are considerably in error, especially for the very bright and very faint apparent magnitudes. This conclusion is supported by the fact that the trigonometric parallaxes of the brighter stars are in general negative, whereas those of the fainter stars are much greater than the values given on the assumption of constant mean luminosity. The real motions of the Class O stars are large and the northerly declination which they give for the apex of solar motion may be explained either as the effect of the well-known asymmetry in the motions of the high-velocity stars or by systematic errors in the proper-motions in declination.

DISTANCE OF THE LARGE MAGELLANIC CLOUD.

The magnitudes of 32 Class O stars in the Large Magellanic Cloud were published by Miss Cannon in April 1924.¹ Arguing that the mean luminosities of these stars must be the same regardless of their location, Wilson has estimated, from comparison of the mean luminosities of the brighter, median, and fainter stars in the cloud and in the Galaxy, that the parallax of the Large Magellanic Cloud is $\pi = 0''.000066$, representing a distance of 15,000 parsecs, or about 50,000 light-years. This distance is about the same as the mean of previous estimates of the distance of the Small Magellanic Cloud and adds probability to the suggestion that the two clouds are moving together through space.

SYSTEMATIC ERRORS IN PROPER-MOTIONS.

Three methods of attack on the problem presented by Kapteyn's proposed correction of $+1''.30 \cos \delta$ to the centennial proper-motions in declination of the Preliminary General Catalogue were given in last year's report. The first method indicated was the comparison of the position of the solar apex derived from proper-motions with those derived from radial velocities, from which such corrections might be devised as would force an agreement in the declination of the apex. This method was used by Kapteyn² who based his correction upon the enforced reduction of the Boss-Eddington proper-motion declination, $+35^\circ$, to Campbell's radial velocity declination, $+25^\circ$. The principal weaknesses in the method arise from lack of homogeneity in the data and the methods of rejection. Raymond and Wilson have attacked the problem with a homogeneous list of 2,962 stars, for which both Boss proper-motions and radial velocities are available. 207 stars having radial velocities, corrected for solar motion, greater than 50 km./sec. or proper-motions in

¹ Harvard College Observatory Bulletin No. 801.

Bulletin No. 14, Astronomical Institute of the Netherlands.

excess of $50''$ per century were rejected from both lists and solutions for the coordinates of the solar motion made by different methods and with different divisions of the material.

The general solutions based upon the 2,755 stars remaining after rejection give the following results:

A	D	M or V.	Method.	Data.
271.8 269.1	+32.8 +29.8	5".72 19.55 km.	54 areas 54 areas	Proper-motions. Radial velocities.

Whereas Kapteyn suggested a correction to the proper-motions to account for an outstanding difference between the proper-motion and radial velocity apices of 10° in declination, solutions based upon data referring to the same list of stars indicate a difference of but 3° . If this difference be due only to systematic error in the proper-motions, a correction of $+0''.42 \cos \delta$ would be indicated. It must be recognized, however, that the difference in the two apices may be wholly due to the methods of rejection. While the rejection of stars with peculiar radial velocities in excess of 50 km./sec. certainly eliminates most of the high-velocity stars from the radial velocity solution, the rejection of stars with proper-motion exceeding $50''$ not only eliminates some of the nearer stars with low velocities, but certainly leaves in the proper-motion solutions a good many of the more distant high-velocity stars. As it has been shown that the high-velocity stars in general tend to throw the proper-motion apex north of that derived from radial velocities, the whole difference of 3° may be due to this phenomenon. Little dependence of the size of the correction upon galactic latitude is shown, but it is clear that the stars of early type, B and A, give corrections appreciably smaller than those of the later types.

STELLAR WAVE-LENGTHS.

Albrecht has completed definitive reductions for the measures by Palmer, Wright, and Albrecht of the Southern Mills spectrograms with $H\gamma$ central. The publication and discussion of these data for correlations between stellar wave-length, spectral types, and absolute magnitudes are being temporarily delayed because of the reasonable certainty that it will soon be possible to change the basis for the resulting stellar wave-lengths from the Rowland to the International system.

The K-term in the B-type stars is still under investigation, due to the fact that the complete solution of this problem would contribute important evidence on convection currents in stellar atmospheres and on the Einstein effect. These two phenomena are interlocked in the spectra in such a way that an approximation can probably be more easily obtained for the former than for the latter. In fact, a differential solution, based on such meager data as are readily available, indicates that practically no K-term would be obtained if the radial velocities were derived from the oxygen, nitrogen, and silicon lines alone. Outstanding difficulties are: (a) the duplex character of most of the spectrum lines which are due to elements other than oxygen, nitrogen, and silicon, thus limiting the available material by introducing an uncertainty as to the exact way in which the two components should be blended for normal

wave-lengths, and (b) the uncertainty as to the absolute amounts of radial motions of the different gases involved. $H\gamma$, though possibly double, should be free from the former duplicity, because the separation of the two components is only about 0.01 \AA . Relative to the new laboratory wave-lengths for oxygen, nitrogen, and silicon, Albrecht's stellar wave-length for $H\gamma$ would be about $4,340.67$. This indicates a relative inward drift for hydrogen and probably a higher level in the atmospheres than for oxygen, nitrogen, and silicon. The present evidence favors little or no radial drift for the vapors in which the oxygen and nitrogen lines originate and possibly a moderate downward drift for the silicon vapors. However, the possibility is not excluded that a moderate actual outward motion of these gases may balance and, therefore, mask an Einstein effect. The normal wave-length for $H\gamma$ seems to require a positive correction of approximately 0.04 \AA . In the published measures of Frost and Adams, $H\gamma$ constitutes 8 per cent of the lines employed, while in the measures in volume IX of the Publications of the Lick Observatory $H\gamma$ constitutes 29 per cent of the lines used. The weight with which the error in wave-length of $H\gamma$ entered into the K-term would be more nearly that of the Lick than of the Yerkes data. It seems probable, therefore, that the downward drift of hydrogen contributed about 0.5 km. to the K-term in the B-types.

MOUNT WILSON OBSERVATORY.

GEORGE E. HALE, HONORARY DIRECTOR.
WALTER S. ADAMS, DIRECTOR.

The Observatory has taken part during the year in two undertakings of general interest in which its experience and facilities have offered an especially favorable opportunity for service. The first of these was the design and construction of a vertical telescope and spectrograph for the new building of the National Academy of Sciences in Washington. These were completed during the spring months, and the instruments were assembled and placed in operation in season for the dedication of the building in April. A torsion seismometer of the design by Dr. Anderson and Mr. Wood was also constructed in the instrument shop and added to the apparatus on permanent exhibit at the Academy building. The vertical telescope gives a solar image 6 inches in diameter and is provided with fast and slow-motion controls. The spectrograph is equipped with a motor for moving the spectrum through the field of view, and with a device for observing a comparison spectrum side by side with that of the sun. Used in conjunction with the telescope, it affords excellent opportunity for examination of the solar surface and for observations of the solar spectrum.

The second project in which the Observatory has shared during the year is that of the establishment of a private observatory for solar research by Dr. Hale. Prevented by illness from taking an active part in the observational work on Mount Wilson, Dr. Hale commenced, on his return from Europe, an investigation of the observing conditions on the sun in the vicinity of Pasadena. These led to the conclusion that although the best morning conditions on Mount Wilson probably are not equalled in the valley, during a portion of the day the seeing in Pasadena is sometimes superior. This result appears to be due to the fact that the heated mountain slopes produce injurious convection currents in the middle of the day on Mount Wilson, while in Pasadena the level character of the country reduces the effect of radiation from the ground. It seems probable, therefore, that Dr. Hale's observatory in Pasadena will supplement in many important ways the work of the instruments on Mount Wilson, and at the same time will afford occasional opportunities for observing the sun at times when the mountain top is enveloped in fog. While the principal expense of the construction of the new "Solar Laboratory," as it will be known in the future, will be borne by Dr. Hale personally, the Carnegie Institution of Washington has assisted through the aid of a special grant for equipment, and the Mount Wilson Observatory is cooperating through its departments of design and construction and its optical and instrument shops in the erection of the building and the manufacture of the apparatus. On its completion the building and the lot on which it stands will be transferred by Dr. Hale to the Carnegie Institution, and the Solar Laboratory will be conducted as a permanent branch of the Mount Wilson Observatory.

Two of the Research Associates of the Observatory, Dr. A. A. Michelson and Dr. Henry Norris Russell, have spent a few months in Pasadena during the year, and have contributed notably to the progress of the scientific work,

both through their own investigations and their suggestions with reference to other researches in progress. Of especial value to the members of the staff was a series of informal lectures given by Dr. Russell on the theories and methods employed in the interpretation of spectra on the basis of modern views of atomic structure. The application of these methods, not only to laboratory spectra but to numerous solar and stellar problems, is proving to be one of the most fruitful fields of modern physical research.

An exceptional opportunity afforded to the members of the Staff was that of hearing the course of lectures on the Quantum Theory given by Dr. Paul Ehrenfest, Professor of Physics at the University of Leiden, at the California Institute of Technology. While the work of the Observatory deals primarily with the application to spectra of the results of the quantum theory, a knowledge of the underlying theoretical considerations is essential to its successful use. In three consecutive years the Observatory has had the opportunity of sharing with the California Institute the privilege of hearing lectures on this and related subjects from the three great physicists, Lorentz, Sommerfeld, and Ehrenfest.

The total solar eclipse of September 10, 1923, proved a severe disappointment to nearly all the expeditions on the Pacific Coast, an extensive clouded area which reached far into Mexico preventing observations at the two stations within the belt of totality, Point Loma and Lakeside, as well as at Mount Wilson itself. It is a matter for especial regret that the apparatus designed for interference and radiometric measurements could not be tried at this time, but it seems probable that some of the smaller instruments designed in the course of these preparations will be exceptionally well adapted for use at future eclipses in less accessible locations.

During the week following the eclipse the American Astronomical Society, the Astronomical Society of the Pacific, and Section D of the American Association for the Advancement of Science held joint meetings in Los Angeles and Pasadena, and at Mount Wilson. The meetings had a large attendance owing to the number of eclipse expeditions planned for Southern California and vicinity. The closing session was held in the dome of the 100-inch telescope and favorable weather afforded excellent observing conditions to visiting astronomers and other scientists.

STAFF.

Dr. George E. Hale, Honorary Director of the Observatory, returned from Europe in October and has been engaged in a study of its general research problems, especially such as relate to solar investigation. He has devoted much time to plans for the Solar Laboratory. Dr. Walter S. Adams, Director, has carried on the administrative work of the Observatory and has continued his investigations in stellar spectroscopy.

Professor Frederick H. Seares, editor of the publications and superintendent of the Computing Division, has been engaged in researches in stellar photometry and stellar statistics. Dr. Arthur S. King, superintendent of the Physical Laboratory, has made extensive studies of laboratory spectra in the arc, spark, and electric furnace, and has extended his classification of spectral lines. Dr. Charles E. St. John has continued his work in solar spectroscopy with particular reference to the gravitational shift of spectral lines, the solar rotation, and convection currents in the sun's atmosphere.

Dr. John A. Anderson has given much time to the design and completion of the new high-voltage condenser and to its use in the study of the spectra of powerful discharges. He has also carried on his studies of the vacuum spark and his tests of diffraction gratings. Mr. Harold D. Babcock has made some special investigations of the Zeeman effect, and has extended his measurements of the wave-lengths of lines in the sun and in laboratory sources with the interferometer. Mr. Francis G. Pease has remained in charge of the design of instruments and apparatus and has made observations with the 20-foot interferometer. Dr. Paul W. Merrill has been engaged in further studies of the spectra of long-period variable stars and of B-type stars with bright lines. Dr. Adriaan van Maanen has continued his determinations of stellar parallaxes and proper motions. Professor Alfred H. Joy, secretary of the Observatory, has been engaged in measurements of radial velocity and spectroscopic parallaxes, and in studies of the spectra of variable stars. Dr. Gustaf Strömberg has carried on further statistical investigations of the motions of the stars in space and of the solar motion as derived from different classes of stars. Dr. Seth B. Nicholson has been in immediate charge of the routine solar observations of the Observatory, and in collaboration with Dr. Pettit has made measurements of stellar and planetary radiation. Dr. Edwin Hubble has continued his studies of the form and nature of nebulae, with especial attention to the great spiral in Andromeda. Dr. Roscoe F. Sanford has determined the orbits of several spectroscopic binaries and has taken part in much other stellar spectroscopic work. Mr. Ferdinand Ellerman has made solar observations and has had general charge of the photographic work of the Observatory. Dr. Edison Pettit has been engaged principally in measurements of radiation with thermo-couples, but has also taken part in the solar investigations. Mr. Milton L. Humason has continued the determination of spectral types and radial velocities of stars in the Selected Areas, and has photographed the spectra of numerous faint stars of especial interest. Mr. Wendell P. Hoge assisted during a portion of the year in the stellar spectroscopic work. Dr. Sinclair Smith has carried on in the laboratory investigations on electrically exploded wires, and has assisted in the general laboratory work as well as in Dr. Michelson's researches.

In the Computing Division Miss Mayberry has continued her measurements of lines in the spectrum of sun-spots and the cataloging of sun-spot positions and polarities under the direction of Dr. Hale and Dr. Nicholson. Miss Ware and Mr. Edward F. Adams have assisted Dr. St. John in his solar investigations. Miss Ware has also used the registering microphotometer in making intensity curves of solar and stellar spectra. Miss Joyner and Miss Richmond have been engaged in photometric reductions under the direction of Professor Seares. Mrs. Marsh has assisted Dr. Van Maanen in measurements of the parallaxes and proper motions of stars. In the department of stellar spectroscopy Miss Burwell has been associated with Dr. Merrill's studies of variable stars, and Miss Brayton, Miss Fretz, Miss Poole, and Miss Wiberg have measured and reduced the stellar spectrograms obtained in the course of the general observing program. Miss Keener, who has been engaged in the work of the Physical Laboratory, resigned her position on May 1. Mr. Wendell P. Hoge, for many years night assistant with the 60-inch telescope, was appointed to this position. Miss Conner has continued in charge of the library and has assisted in the editorial work. During the temporary absence of Miss Connor, Miss Gilder has been appointed as librarian.

Dr. Henri L. Vanderlinden, of the Royal Observatory of Belgium, has been a volunteer assistant at the Observatory since September 1, 1923. His investigations have dealt mainly with the effective wave-lengths and spectra of numerous faint stars and nuclear condensations. He has also carried on theoretical researches relating to certain problems in the relativity theory of gravitation. Dr. S. A. Mitchell, director of the Leander McCormick Observatory, came to Pasadena in June and spent the summer months at the Observatory. Mr. John A. Carroll, Isaac Newton student of Cambridge University and Research Fellow in Physics in the Norman Bridge Laboratory of the California Institute of Technology, has carried on investigations in the Physical Laboratory on the vacuum spark spectra of several elements. Dr. J. H. Oort of the Leiden Observatory is spending two months at the Observatory as volunteer assistant and is engaged in stellar spectroscopic investigations. Professor I. Yamamoto, of the University of Kyoto, who was volunteer assistant for several months, left Pasadena in October 1923. Professor Margaret Harwood, Director of the Maria Mitchell Observatory, was at Mount Wilson between September 1923 and May 1924, and was engaged in photometric researches and observations of the asteroid Eros with the 60-inch and 10-inch telescopes.

Dr. A. A. Michelson, of the University of Chicago, Research Associate, returned to Mount Wilson on June 10 to continue his investigation of the velocity of light. Dr. Henry Norris Russell, of Princeton University, Research Associate, spent the months of April and May at the Observatory and was engaged in studies of regularities in spectra and their astrophysical applications.

OUTLINE OF THE YEAR'S WORK.

Two results of the first importance have characterized the solar investigations of the year. The first of these is the confirmation by Hale and his associates of the reversal of the polarities of sun-spots at minimum, a result first suspected in 1912 and described by Hale, Ellerman, Nicholson, and Joy at that time, but requiring a second period of minimum activity for final decision. This discovery can not fail to be of vital significance in its bearing on sun-spot theory and the cycle of solar activity.

The confirmation by St. John of the gravitational shift of the lines in the solar spectrum seems to afford final evidence for the validity of the theory of general relativity. St. John's results, based upon over 330 iron lines, show in a simple and convincing way the effect of the combination of the relativity displacement with that due to convection currents in the solar atmosphere and explain many of the difficulties encountered by observers in this field.

Of the other results obtained in the department of solar research, reference should be made to the work of St. John and Babcock on pressure in the sun's atmosphere, which confirms by direct methods the conclusion that the pressures in the reversing layer are extremely low; to the progress made by St. John and Babcock in the determination of the wave-lengths of standard solar lines; to Nicholson's compilations of sun-spot numbers and polarities; and to Pettit's observations of the ultra-violet radiation of the sun.

In the field of stellar astronomy the investigations of Seares on the distribution functions of stellar velocities and the form of the luminosity function

have led to results of great interest. Expressions have been derived for the forms of the velocity and luminosity functions and the coefficients involved, which show an excellent degree of accordance with observation and provide a valuable basis for theoretical studies of velocities, mean parallax, and stellar density. Strömberg has continued his study of the asymmetry of stellar motions and finds a sequence among the stars in accordance with which the group-motion changes in a regular way with the dispersion in velocity. This leads to most interesting hypotheses as to the conditions governing the distribution of stellar motions.

Among other results of interest in this field are the discovery by Hubble of several variable stars in the great spiral nebula of Andromeda, from a study of which the distance of the nebula probably can be determined with considerable precision; the investigation by St. John and Adams of the relative displacements of lines in the spectra of certain stars and the evidence thus afforded of the existence of convection currents in their atmospheres; the radiometric observations of Pettit and Nicholson of stars and planets and the evidence they afford regarding planetary atmospheres and probable rotation periods; the additions to trigonometric parallaxes made by van Maanen; the conclusions drawn by Merrill and Strömberg regarding the absolute magnitudes of the long-period variable stars and the nature of their motions in space; the detailed study by Joy of the remarkable spectrum of α Ceti and the prediction of its binary character; the investigation by Sanford of the radial velocities of the R-type stars and of numerous spectroscopic binaries; the determination of the radial velocities of many additional stars and the development of further methods for obtaining spectroscopic parallaxes; and the spectroscopic investigations by Humason of faint stars in globular clusters and in Kapteyn's Selected Areas.

In the physical laboratory the work of the year has included the temperature classification of the lines in the ultra-violet spectra of vanadium and chromium by King and the measurement of the wave-lengths of many new lines; the continuation by Anderson of his studies with the vacuum spark of the spectra of oxygen and nitrogen, and by Carroll of several other elements; a special investigation by Babcock of the Zeeman effect for vanadium, which has resulted in an improvement in the values of the observed separations of close components and has eliminated practically all the inconsistencies with the results required by the quantum theory; an interesting study by Sinclair Smith of the spectrum of electrically exploded wires in which, by the aid of a special device for moving the spectrum rapidly, a photograph could be made showing the variation of the spectrum during the period of the explosion; further investigations by King of the successive stages in the development of the ionized spectrum of some of the elements with numerous lines, and the use of a direct current arc with currents of the order of 1,000 amperes to produce spectra intermediate between that of the ordinary arc and that of the spark; and the continuation by Babcock of interferometer measurements of standards of wave-lengths, more especially such as belong to the system of secondary standards.

A very complete analysis of the arc and spark spectrum of titanium has been carried out by Dr. Russell, Research Associate, during the year. Almost without exception, every important line has been classified according to the energy level involved in the atom and its relationship in the system of spectral

regularities. From the results of his own work and that of other investigators, Dr. Russell has compiled a list of all the more important lines of the elements which have been studied for spectral regularities which are likely to prove of astrophysical importance. Within the short period of its existence this list has already found many valuable uses.

A most successful application of the radiometer to the measurement of the spectral radiation of the brighter stars was made by Dr. Charles G. Abbot, Director of the Astrophysical Observatory of the Smithsonian Institution, in October of last year. Using the 100-inch telescope and a special optical system devised for the purpose, he secured measurements of the energy radiation from nine stars in regions of the spectrum extending from the ultra-violet to $2.2\ \mu$ in the infra-red. The comparison of the results with those of a black body radiator and the conclusions regarding surface luminosity and dimensions of the stars of the different spectral types are of the greatest interest.

OBSERVING CONDITIONS.

The winter season of 1923-24 was characterized by abnormally low precipitation and less than the average amount of cloudiness for this period of the year. As usually happens, however, in a dry season the prevalence of northerly winds from the direction of the Mojave desert produced poor conditions of seeing during much of the time when the sky was clear. The precipitation for the year was the lowest since the establishment of the Observatory, 16.87 inches as compared with a 20-year average of 33.72 inches. The total snowfall was 39 inches. The highest temperature recorded during the 10 months between September 1 and June 30 was 98° on September 8, and the lowest was 17° on January 1. There were several heavy windstorms during the winter months, a maximum velocity of 92 miles an hour being reached in a storm on January 9.

The following table gives the observing record with the 60-inch reflector for the period of 10 months from September to June. The hours when no observations were made include those lost not only through cloudiness but also through poor seeing, and all other causes. During September the preparations for the solar eclipse and the meetings of the Astronomical Societies caused some interruption in the regular observing program.

Month.	Hours of darkness.	Hours of observations.	No. observations.	Observed.		
				All night.	Part of night.	None.
1923						
September.....	295	123	172	10	6	14
October.....	336	202	134	17	7	7
November.....	330	126	204	9	8	13
December.....	346	103	243	7	6	18
1924						
January.....	346	163	183	11	11	9
February.....	308	193	115	14	13	2
March.....	324	93	231	4	11	16
April.....	286	129	157	11	7	12
May.....	266	195	71	13	15	3
June.....	230	206	24	10	19	1

The 60-inch reflector has been available for public use on every Friday night throughout the year, and about 2,500 persons have made observations with the instrument during the past 10 months. Within the same period 11,000 persons have visited the museum and inspected the 100-inch telescope during daylight hours. In cooperation with the Mount Wilson Hotel an arrangement was entered into in May in accordance with which Wendell P. Hoge, of the Computing Division, visits Mount Wilson every Friday night and gives an illustrated public lecture preceding the observations with the 60-inch telescope. This plan has added materially to the successful use of the public nights.

SOLAR RESEARCH.

The sun-spot activity during the closing months of 1923 and the first 4 months of 1924 was extremely low, but during May and June the activity increased to such an extent that it seems certain that the minimum has passed. The increase of the number of spots in high latitudes, which doubtless belong to the new cycle, makes the present stage of solar activity a most important one, and all sun-spot groups are under careful observation. The general state of the sun's surface is still so undisturbed, however, that observations which require quiescent conditions may still be made satisfactorily.

SOLAR PHOTOGRAPHY.

Direct photography of the sun and observations with the spectroheliograph have been continued regularly with the 60-foot tower telescope by Ellerman, Nicholson, Pettit, and L. H. Humason. During the 10 months from September 1, 1923, to June 30, 1924, the following photographs have been obtained:

Photoheliograms of the 6.5-inch image, 507 on 251 days.

Spectroheliograms of the 6.5-inch image with the 5-foot spectroheliograph in H_{α} light, 131 on 131 days.

Spectroheliograms with the 13-foot spectroheliograph in K and H_{α} light of the 2-inch image, of prominences and of portions of the 6.5-inch image, 756 on 252 days.

In accordance with the plans of the International Astronomical Union for cooperative investigation, reports have been made monthly to the Director of the Kodaikanal Observatory of the days on which spectroheliograms of prominences and of the sun's surface have been obtained. Copies of the photographs necessary to complete the records at Kodaikanal have been sent to that observatory.

SUN-SPOT ACTIVITY.

The number of sun-spot groups observed during the calendar year 1923 was 37, as compared with 78 in 1922. Of these, 23 were in northern and 14 in southern latitudes. No spots were visible at the time of observation on 170 of the 320 days on which the sun was observed during 1923. The average number of groups observed daily in each month was as follows:

Month.	Daily number.		Month.	Daily number.	
	1922	1923		1922	1923
January.....	1.3	0.4	August.....	0.5	0.3
February.....	2.1	0.1	September.....	0.6	1.2
March.....	3.0	0.3	October.....	0.9	1.2
April.....	1.4	0.6	November.....	0.8	0.9
May.....	0.6	0.4	December.....	1.4	0.4
June.....	0.8	0.8			
July.....	1.1	0.4	Yearly average..	1.2	0.6

The solar activity during the first four months of 1924 was as low as that for any similar period of 1923, but during May and June the activity increased considerably. As the above table shows, the exact time of the minimum can not be determined with great exactness.

The activity in high latitudes increased as that in low latitudes decreased, so that during the year there have been two distinct sun-spot zones in each hemisphere. There were 21 groups in low latitudes with an average distance from the equator of 7°2, and 16 in the zones of high latitude at an average distance of 27°4 from the equator.

SUN-SPOT POLARITIES.

The daily determination of the polarities and intensities of the magnetic fields of each sun-spot group has been continued throughout the year. As described in detail below, the distribution of magnetic polarities in spot groups of the new cycle is exactly opposite to that for groups of the old cycle. The following table summarizes the results of the observations of the polarity of spots. In this table "old" refers to the groups in low latitudes belonging to the old cycle and "new" refers to groups of the new cycle which are in the zones of higher latitude.

Hemisphere.	Polarity.					
	Regular.		Irregular.		Undetermined.	
	Old.	New.	Old.	New.	Old.	New.
North.....	13	8	0	0	2	0
South.....	5	8	0	0	1	0
Whole Sun.....	18	16	0	0	3	0

A summary of the magnetic observations of sun-spots, including the classification of all spot-groups according to their magnetic fields, has been printed every two months in the Publications of the Astronomical Society of the Pacific. Miss Mayberry and L. H. Humason have assisted in the preparation of these records.

THE LAW OF SUN-SPOT POLARITY.

In the last annual report the first indications of a general reversal of sun-spot polarities, similar to that observed in 1912-1913, were mentioned. Subsequent observations have fully confirmed these early results, and have permitted Hale and his associates to formulate a tentative law of sun-spot polarity, based on observations of more than 2,000 spot groups from 1908 to 1924.

Before the minimum of 1913 the polarity of preceding spots in the northern hemisphere was S (south-seeking pole) or negative, and that of the following spots N or positive. The spots of the southern hemisphere gave opposite polarities, *i. e.*, N for preceding and S for the following members.

To our surprise, the high latitude spots of the new cycle, which began in 1912, were opposite in polarity to the low latitude spots of the old cycle. As the new cycle advanced and the spots became more and more numerous, the new polarities were found to characterize all spots observed, with only

about 4 per cent of exceptions. The average latitude of the spots gradually decreased, in the customary way, and the recent spots marking the end of the cycle have been very near the equator, though several observed in 1923 reached latitudes as high as 15° .

The first spot of the next (present) cycle appeared on June 24, 1922, at latitude 31° N. After a long interval several other spots of this cycle were observed, including a number of bipolar groups. They again showed a reversal of polarity, reverting to the conditions existing before the minimum of 1913.

It thus appears that, within the period stated, the spots in each new cycle show a reversal of polarity. Near the time of minimum 4 spot zones, characterized by distinct magnetic polarities, may co-exist on the sun. This condition lasts only 2 or 3 years, after which the low latitude spots of the old cycle disappear.

We can not yet determine with certainty the sign of the dominant electric charge in the spot vortex. If it is always the same, the vortices of the preceding and following spots of bipolar groups must whirl in opposite directions. The reversed polarities of corresponding spots (preceding and following) of successive cycles in the same hemisphere also indicate opposite directions of whirl.

The sun-spot period, if defined in the usual way as representing the variation in the number of total area of all spots on the sun, is approximately 11 years. But if we regard the period as the interval between successive appearances of spots of the same magnetic polarity, the present results indicate that it is twice as long.

THE SPECTROHELIOSCOPE.

In the early days of solar prominence observations, before the open slit method had come into use, Zöllner, Young, and other astronomers employed an oscillating spectroscopic slit, with a second slit set on $H\alpha$ and oscillated synchronously, as a means of revealing prominence forms. This device does not seem to have survived the introduction of the open-slit method, and apparently it was not tried for observations of phenomena on the sun's disk.

During last winter, with the aid of a cœlostæt, a 12-inch objective, and a 13-foot spectroscopic telescope temporarily set up in the garden of his residence, Hale perfected an instrument based on this principle, which permits not only the forms of the prominences at the limb, but also both dark and bright hydrogen flocculi on the disk, to be observed visually. A straight bar oscillated by an electric motor, carrying from 1 to 5 first slits and an equal number of second slits, or a rotating disk pierced with a large number of radial slits may be employed. In the very bright first order of a 6-inch grating, made by Jacomini for this purpose on our ruling machine, the $H\alpha$ line is about 0.006 inch wide. With slits of half this width, a high degree of purity in the monochromatic image is attained. As the slits can be moved by a micrometer screw during observations, so as to permit a quick comparison of the forms given by different parts of the $H\alpha$ line, the instrument promises to be a useful auxiliary of the spectroheliograph, especially for the study of eruptive phenomena. It will naturally be called a spectrohelioscope.

SOLAR ROTATION.

St. John, assisted by Miss Ware, has continued his spectroscopic investigation of the rotation of the sun. The 150-foot tower telescope and the 75-foot spectrograph have been used for all the observations. Measurements of the displacements of the lines in the red portion of the spectrum for a region near the solar equator show no evidence of change over the results for previous years.

WAVE-LENGTHS OF LINES IN THE SOLAR SPECTRUM.

The number of solar lines with wave-lengths determined upon the international system has been increased considerably during the year. St. John has used the grating spectrograph of the 150-foot tower telescope, and Babcock the interference apparatus and auxiliary spectrograph of the physical laboratory which have been employed in measurements of standards of wave-length in arc spectra. A new cœlostæt constructed for this purpose and a concave grating ruled by Jacomini will be used by Babcock to complete his observations.

PRESSURE IN THE SOLAR ATMOSPHERE.

Reference was made in last year's report to the method used by St. John to obtain a direct calculation of the pressure in the sun's reversing layer by the aid of lines whose pressure displacements differ in laboratory sources. St. John and Babcock have utilized the additional measurements of solar wave-lengths of iron lines and new laboratory data on pressure displacements to secure a more accurate evaluation of this quantity. Care has been taken to avoid pole effect in the laboratory observations, and to eliminate, as far as possible, the influence of radial motion, the relativity displacement, and differences of level in the solar atmosphere. The resulting value of 0.13 ± 0.06 atm. for the lower few hundred kilometers of the reversing layer is in good agreement with that indicated by several theoretical lines of evidence.

The very low value found for the pressures in the sun's atmosphere removes restrictions formerly placed on the selection of material for this study and simplifies greatly the interpretation of solar displacements.

GENERAL RELATIVITY AND THE DISPLACEMENTS OF SOLAR LINES.

The causes of the differences in wave-length of spectral lines in the sun and in the vacuum arc have been under investigation by St. John for several years. Particularly from the point of view of general relativity, the question is of the utmost importance, and the results which St. John has now obtained seem to give convincing evidence of the nature of the phenomena which combine to give the displacements observed.

The generalized theory of relativity requires a systematic displacement of all lines in the solar spectrum toward longer wave-lengths. The tendency toward such a displacement has long been recognized, but the discordance between the amounts observed and those deduced from the theory has proved a serious difficulty. In particular, it has been found that the stronger lines show larger and the weaker lines smaller displacements than the theory requires, while lines of medium intensity give results in substantial agreement. The accompanying table illustrates the displacements (sun *minus* vacuum-arc) of lines of different intensities as observed and as calculated from the theory of relativity.

Group.	No. of lines.	Solar intensity.	Mean wave-length.	Observed.	Calculated.	Obs - Cal.	Velocity.
				<i>A</i>	<i>A</i>	<i>A</i>	<i>km./sec.</i>
<i>a</i>	17	12	3286	0.012	0.008	+0.004	+0.3
<i>b</i>	24	14	3821	0.0112	0.008	+0.0032	+0.25
<i>b</i>	10	10.4	4308	0.0113	0.0091	+0.0022	+0.16
<i>a</i>	10	6.2	5443	0.0112	0.0115	-0.0003	
<i>b</i>	131	4.8	4758	0.0084	0.0100	-0.0016	-0.1
<i>d</i>	106	4.5	4763	0.0069	0.0100	-0.0031	-0.2
<i>a</i>	33	3.3	4957	0.0074	0.0105	-0.0031	-0.2

The diversity in the behavior of lines of different intensities St. John ascribes to differences in the effective level in the sun's atmosphere at which the lines are produced and to the presence of convection currents at these levels. That lines originating at various levels do show the characteristic progression in the differences *sun minus arc* is easily substantiated by a study of normal and enhanced lines of the same intensity for various elements appearing in the sun. The enhanced lines are known from eclipse data to rise to much higher levels in the solar atmosphere than normal lines of the same intensity. They also show an excess in their displacements over those calculated from the theory of relativity. This is illustrated by the following results in the case of titanium:

	No. of lines.	Solar intensity.	Sun <i>minus</i> vacuum-arc.	Obs - Cal.	Height.
			<i>A</i>	<i>A</i>	<i>km.</i>
Enh. Ti.....	2	11	+0.015	+0.007	6,000
Enh. Ti.....	8	4.6	+0.0112	+0.002	1,300
Normal Ti.....	5	4.2	+0.0054	-0.0034	435

It is highly probable, therefore, that level in the solar atmosphere, and not the intensity of the lines, is the primary factor in producing the progression in the observed displacements.

Since the low value found for the pressure in the reversing layer eliminates the effect of pressure and of ray curving due to anomalous refraction, there apparently remains for consideration only the effect of radial motions in the gases constituting the sun's atmosphere. Such motions in combination with the effect of general relativity will produce displacements of just the character observed, if the radial velocities are downward at the higher levels and upward near the base of the reversing layer. The very moderate velocities required are indicated in the last column of the table already given.

Independent evidence for the existence of such motions has been afforded by St. John's work in previous years on the nature of the circulation in the solar atmosphere. The results of St. John and Adams for the relative displacements of the spectral lines in the atmospheres of some of the brighter stars also find a simple explanation on this basis. If the currents are upward over the hot, bright granules of the sun's surface and downward over the larger and cooler interspaces, the integrated effect should be a slight widening of the spectral lines produced at low levels, greater on the violet than on the red edge.

The decrease of upward velocity with elevation would bring about a balanced condition at moderate levels, while at still higher levels the influence of the cooler, downward-moving gases would result in an asymmetry on the red edges of the lines.

At the sun's limb, where the radial components of velocity disappear, the displacements of all lines exceed the relativity displacements by small amounts. This excess may perhaps be interpreted as the effect of molecular scattering in accordance with the Rayleigh-Schuster formula. Julius has called attention to the fact that in general the refractive power is greater on the red than on the violet side of an absorption line by twice the refractive power of the solar atmosphere. Since the coefficient of scattering increases as the square of the refractive power, the differential scattering tends to widen the lines on the red edge. At the limb of the sun the greatly lengthened paths through the gaseous layers should favor this differential effect, which would be inappreciable in the shorter paths near the center.

St. John's conclusions, therefore, are that three principal causes produce the differences found between solar and terrestrial wave-lengths. These are the influence of generalized relativity, convection currents of moderate amount in the sun's atmosphere, and differential scattering which becomes effective in the long path of light near the solar limb.

ULTRA-VIOLET SOLAR RADIATION.

A study of the amount of solar radiation transmitted by silvered quartz plates has been commenced by Pettit. Such an investigation was made by Dobson in England, and the purpose of the present work is to secure a comparison with his results and to obtain a series of continuous observations throughout the summer season.

The radiation is recorded by a self-registering device connected with a vacuum thermo-couple. The ultra-violet radiation transmitted by a silvered quartz plate and lens unit, consisting of a band near $\lambda 3100$, and that transmitted by a similar gilded unit and green screen, consisting of a narrow band near $\lambda 4950$, are both measured at intervals of 2 minutes throughout the day. The apparatus is attached to the mounting of the 6-inch refractor and was placed in operation on May 28. No considerable variations have so far been observed.

RESEARCHES ON THE MOON AND PLANETS.

RADIOMETRIC OBSERVATIONS.

During the year Pettit and Nicholson have made about 100 sets of observations with a vacuum thermo-couple of the radiation from the moon and planets. Many of these, especially those of Mercury, Venus, and Mars, were made in full daylight when the planets were near the meridian. A fluorite screen has been added to the number of the transmission cells used to study the spectral distribution of the radiation. This screen divides Fowle's atmospheric transmission band between 8μ and 14μ into two parts, both of which can be used in temperature studies.

Observations of the distribution of radiation over the surface of the moon show that this agrees closely with that which is to be expected from a planet without an atmosphere. The total radiation from the dark markings is nearly, though not quite, as great as that from the bright areas. The crater Mösting A was observed at the request of Professor Pickering, and the prop-

erties of its radiation seem to be typical of those of small bright craters having the same appearance at full moon.

Mercury has been under observation during the entire year, over a range of phase angle from 32° to 120° . The radiometric magnitude of Mercury according to these observations, when reduced to full phase and to such a distance as to present an angular area of π square seconds of arc, is approximately zero.

Venus has also been observed over a wide range of phase angles. The bright side of the planet emits about 8 per cent of planetary radiation, a quantity which does not change markedly with the phase. Observations made on the dark side of the planet near inferior conjunction show a large amount of radiation of such long wave-length that even fluorite transmits only a small percentage of it. This indicates a low temperature, possibly near the freezing point, and further observations may yield definite information regarding the nature of the rotation of the planet.

Mars has been found to give nearly equal amounts of planetary radiation and reflected sunlight, a result which is in agreement with the theory of a rare atmosphere. In the case of Jupiter, measures made at the center and the limb show a marked difference, both in the amount and the quality of the radiation.

In the interpretation of measures of planetary radiation, the study of nocturnal radiation from the thermo-couple to space, and from the atmosphere to the thermo-couple, is of great importance. This applies particularly to thermo-couples such as that used on the moon, in which one junction is shielded. The radiation from a thermo-couple which is not compensated by the atmosphere decreases with the air mass in much the same way as does planetary radiation.

SATELLITES OF JUPITER AND SATURN.

Photographs of the Eighth Satellite of Jupiter made at the opposition of 1923 have been measured for position by Nicholson, and photographs of the Ninth Satellite of both Jupiter and Saturn have been secured at the 1924 opposition. The orbit of the Ninth Satellite of Jupiter has been brought forward by application of special perturbations and an ephemeris calculated for the 1924 opposition.

RESEARCHES ON NEBULÆ.

DIRECT PHOTOGRAPHY.

The program of direct photography of nebulæ has been continued principally by Hubble, although Humason has made several photographs of spirals with the 100-inch Hooker telescope for use in the study of internal motions, and of the great nebula in Andromeda for the detection of novæ. Exposures on N. G. C. 7662 were also made by Pease during the readjustment of the 100-inch mirror in its cell.

Hubble has accumulated data for a special study of dark markings in planetaries. This program, for which the Hooker telescope is used, requires unusually good observing conditions, and hence progresses slowly. Convincing evidence of absorption by dark or feebly luminous nebulosity has been found in the cases of N. G. C. 6309, 6741, and 7027.

Plates of 65 non-galactic nebulæ in Holetschek's list, not previously photographed on any adequate scale, have also been obtained by Hubble for pur-

poses of classification. The ultimate object is the accumulation of homogeneous data on non-galactic nebulae, reasonably complete to definite limits, for statistical study.

NOVÆ AND VARIABLES IN M 31.

Special attention has been given to M 31, the great spiral in Andromeda. Ten novæ and six variable stars have been found by Hubble within limits of the nebular image. The novæ have been given the serial numbers 23 to 32, inclusive. No. 26, the faintest, was detected on the photograph of October 4, 1923, but reference to the large collection of plates covering the last 15 years indicates that this nova appeared some time between February 7 and August 1, 1921, and has remained at constant brightness since the latter date. Three of the novæ are farther from the nucleus of the nebula than any previously observed. Of these three, No. 30, 12'6" south of the nucleus, is the most distant.

The variable stars appear to be distributed in a manner complementary to that of the novæ. The novæ frequent the inner regions of amorphous nebulosity, but the variables are found far out where the spiral arms have broken up into swarms of stars, or, at least, into condensations which can not be distinguished from stars with the highest resolving power available. The variables are all faint, the brightest, No. 1, reaching a maximum estimated at about the eighteenth photographic magnitude. A light curve for this star, determined from 83 well-distributed observations, shows the typical Cepheid characteristics. The period is 31.415 days, the estimated median photographic magnitude is about 18.5 and the range about 1.2 magnitudes. Light curves for the fainter variables have not yet been determined.

N. G. C. 6822.

Four new variable stars in addition to the 12 previously known have been found by Hubble in N. G. C. 6822, an irregular cluster of the type of the Magellanic clouds. A spectrogram of one of the patches of diffuse nebulosity connected with the cluster gives a radial velocity, uncorrected for the solar motion, of 25 km./sec., as determined from the nebular lines N_1 and N_2 .

RESEARCHES ON STARS.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS.

During the year van Maanen has obtained 149 plates with 260 exposures at the 80-foot focus of the 60-inch reflector, and 127 plates with 231 exposures at the 42-foot focus of the 100-inch telescope.

Parallaxes were derived for 25 fields, bringing the total number of finished parallaxes to 191, while for three other fields the necessary photographs have been obtained, but are not yet measured.

A dozen fields have now been completed with the 100-inch telescope. The mean probable error of a parallax determined from 16 exposures is about 0".006, which is only slightly larger than that for the 80-foot focus of the 60-inch reflector, notwithstanding the fact that the focal length used with the Hooker telescope is only 42 feet. This small probable error may be explained partly by the fact that, as a whole, very faint comparison stars close to the central star have been used, and partly by the ease with which the images on the 100-inch photographs are measured, as compared with those on plates taken with the 60-inch telescope.

Among the objects of especial interest for which the parallaxes have been determined are the following faint stars of large proper motion:

	Phot. Mag.	π rel.	μ	M
Wolf 134	15.2	+0".052	1".74	+12.8
" 219	14.3	+0.070	1.25	+13.5
" 358	13.2	+0.131	1.19	+13.8
" 629	12.3	+0.190	1.26	+13.7
" 630	10.4	+0.187	1.23	+11.8

On the plates of the last two stars a variable was discovered 2'.4 west and 3'.6 south of B. D. $-7^{\circ} 4373$; the magnitude ranges from at least 12.5 to 16.9.

The star HD 7307, spectral Class M, whose brightness and proper motion suggest an absolute magnitude intermediate to those of the giants and dwarfs, was found to have a relative parallax of +0".012. The corresponding absolute magnitude is +3.9.

Relative parallaxes have also been derived for two novæ: Nova Ophiuchi No. 4, $-0".005 \pm 0".008$; and Nova Cygni 1920, $+0".003 \pm 0".005$.

Parallaxes have now been measured with the 100-inch telescope for four planetaries, viz: N. G. C. 6720, 6778, 6853, and 7293. With 0".001 as the correction from relative to absolute parallax, the absolute magnitudes of the central stars are +7.1, +8.7, +8.9, and +11.3, respectively. Their agreement with values derived from photographs taken with the 60-inch reflector, which give $M = +7.4$ for the mean of 16 central stars, strengthens our confidence in the general character of the results. It is difficult, however, to reconcile these faint absolute magnitudes with the small proper motions usually accepted as characteristic of the planetary nebulæ, and the work on the determination of proper motions of the planetaries is accordingly being continued by van Maanen and Mrs. Marsh.

Mrs. Marsh has measured 8 more sets of plates for the determination of the proper motions of the comparison stars used in the measurement of the parallaxes of stars in Boss's Catalogue. The 38 fields for which proper motions have now been derived have been discussed by Dr. Oort in a preliminary attempt to determine the systematic error in Boss's proper motions feared by Kapteyn. By assuming the declination of the apex for the stars of twelfth and thirteenth magnitudes to be the same as for the brighter stars, the systematic error in Boss's proper motions in declination is found to be $-0".0054 \pm 0".0014$. If, however, the declination of the apex for these faint stars is assumed to be $+60^{\circ}$ instead of $+30^{\circ}$, the correction disappears. More material is necessary before definite conclusions can be drawn.

Van Maanen has recently measured two pairs of plates taken at intervals of 11 and 9 years, respectively, of M 13, the great globular cluster in Hercules. While the reductions are not yet complete, the results are far enough advanced to show that the proper motion of the cluster is extremely small—of the order of a few thousandths of a second of arc. The internal motions also appear to be very small, if not wholly inappreciable. While this result is negative, as far as motions are concerned, it is gratifying in that it gives another proof that the internal motions found by van Maanen in the

spiral nebulae can not be explained by peculiarities, either in the 60-inch reflector or in the measuring apparatus used.

STELLAR PHOTOMETRY.

The photographic work in photometry by Seares has been mainly the completion of the observations of the colors of the stars in the 24 Selected Areas of the zone at $+30^\circ$ declination. An unusual amount of thin cirrus cloud has greatly interfered with the observations, but one or more exposure-ratio photographs with exposures of 64 minutes to yellow light are now available for each area, in addition to two or three plates of shorter exposure.

Hubble has continued the systematic determination of the magnitudes and color indices of the central stars of the planetary nebulae for which spectra have already been obtained. The great strength of the continuous spectrum of these stars in the region of short wave-lengths suggests the importance of measures of their ultra-violet light. Some experimental work has been done with an ultra-violet filter; but all photometric work on these stars is complicated by the presence of the adjacent nebulosity.

Vanderlinden, using the objective grating of parallel wires on the 60-inch reflector, has obtained a large number of photographs for the photometric study of the open clusters M 44 and 67, the central stars in the giant planetary nebulae, certain faint variables in Lacerta, and the colors of the nuclear condensations of the spiral M 51 and various peculiar stars of large proper motion and known parallax.

Humason, using ammoniated Ilford panchromatic plates and a red filter, has made several long exposures in a search for very red stars, similar to the remarkable object discovered by von Zeipel near M 37. The indications are that stars having color indices greater than 2 magnitudes are exceedingly rare.

From polar comparisons Seares has found for von Zeipel's star a photo-visual magnitude of 12.86 and a provisional photographic magnitude of 17.85. The color index is therefore approximately 5.0 magnitudes.

The counts of the stars in the catalogue of photographic magnitudes for Selected Areas 1 to 139 have been completed by Miss Joyner and Miss Richmond, and are ready for statistical discussion.

Especially important, as a supplement to these data, are the results of the *Durchmusterung of Selected Areas* by Professors Pickering and Kapteyn, published in Harvard Annals, 101. The magnitudes of this catalogue are referred to the scale of Harvard Annals, 73, and, as compared with the international scale, are affected by a large color equation. The reductions to the international system have been determined by comparisons of the overlapping portions of the *Durchmusterung* and the Mount Wilson catalogue. The corrections thus found agree with those to be anticipated from the known characteristics of the Harvard scale and the mean colors of the stars involved.

Several studies, mainly of a photometric character, were carried on by Miss Harwood during her stay at the Observatory. These included measures of the color indices of the central stars of three planetary nebulae, N.G.C., 1952, 2392, and 3587, on photographs taken with the 60-inch reflector, observations of the brightness of Eros on negatives secured with the 10-inch photographic telescope, and color determinations for several other objects. Miss Harwood also photographed the Gegenschein with a short-focus lens attached to the 10-inch telescope.

STELLAR SPECTROSCOPY.

The instrumental equipment in the department of stellar spectroscopy has remained essentially without change during the year. The large spectrograph for use at the coudé focus of the 100-inch reflector has been completed and is now being installed in the constant temperature room on the south side of the dome. The 10-inch camera lens designed by Moffitt for use in the Cassegrain spectrograph on the 100-inch telescope has proved of great value and has been employed with increasing frequency as the work with this instrument has come to deal with fainter stars.

In the period between September 1 and June 30 a total of 1,106 spectrograms was obtained with the two Cassegrain spectrographs, 435 with the 100-inch telescope, and 671 with the 60-inch telescope. About 30 per cent of the spectrograms taken with the 100-inch telescope were of stars fainter than the ninth visual magnitude. The observing list with the 60-inch telescope has consisted mainly of stars in Boss's catalogue and of stars with dynamical parallaxes by Russell, while the larger instrument has been employed chiefly for faint stars of large proper motion and a considerable number of variables of different types.

RADIAL VELOCITIES.

The progress in the determination of radial velocities may be summarized partially under a few general headings.

(1) The velocities of about 140 stars have been determined from measurements of 3 or more spectrograms. A considerable portion of these are of dwarf stars fainter than the eighth magnitude visually.

(2) A list of 97 spectroscopic binaries discovered during recent years at Mount Wilson by Adams, Joy, and Sanford has been published preparatory to inclusion in the catalogue of spectroscopic binaries now being compiled at the Lick Observatory. Among these are numerous variable stars of the Algol type, Cepheids, and short-period variables.

(3) Special attention has been given by Joy and Adams to cluster-type variables with periods less than a day, on account of their large motions in space and their relationship to Cepheids. The average radial velocity for 27 of these stars is 87 km./sec. Additional observations of VX Herculis indicate a velocity of -390 km./sec., which is the greatest velocity so far observed for any star. From the velocity curve of SW Andromedæ, Joy has found indications of a change of period. This change, which has a period of 1,930 days, is confirmed by photometric observations of maxima extending over 11 years.

(4) Joy has obtained spectrograms of several variable stars with periods intermediate between those of ordinary Cepheids and long-period variables. Their spectra are for the most part of type M without bright lines, and their velocities, like those of Me variables, are exceptionally large.

(5) Sanford has continued his observations of spectroscopic binaries and has secured 189 spectrograms during the past 10 months. The orbits of four stars, H. D. 27130, H. D. 96511, Boss 1131, and B. D. $+55^{\circ}$ 2215 have been determined, and several others require but few additional observations for completion.

(6) Sanford has also photographed the spectra of several stars, including α Orionis and spectroscopic binaries of early type, with a dispersion of 5 Å to the millimeter at H γ . These spectrograms have been used not only for determinations of radial velocity but for critical studies of line-intensity.

(7) Humason has continued observations of stars in the Selected Areas. With a view to reducing the great amount of observing required in Kapteyn's original plan, Dr. van Rhijn has prepared a revision of the list of stars in these areas. The revised program includes 406 stars to a limiting visual magnitude of 8.5, as compared with 1,392 stars to a limiting magnitude of 9.0 in the previous list.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX.

It has been clear from the beginning that the variation with absolute magnitude in the intensities of certain lines used for deriving the luminosity of stars is but a part of a general effect dependent upon density and temperature in the stellar atmospheres. A giant star is bright intrinsically, because it is extremely large as compared with a dwarf star of similar spectral type. The temperature of the giant star is below that of the corresponding dwarf and the density of its atmosphere is exceedingly low. These physical conditions produce definite characteristics in the spectra of intensely bright stars, of which the most important are the sharpness and narrowness of all lines, the great prominence of the enhanced lines, and the intensification of low-temperature lines, especially in stars themselves at low temperature.

A study of the spectral characteristics of M-type stars by Adams and Joy illustrates these considerations. It had been recognized previously that nearly all the bright lines of iron which appear in the spectrum of α Ceti shortly after maximum of light are low-temperature lines and belong to multiplets from nearly the same energy level in the atom. An examination of these lines showed them to be greatly strengthened in the spectrum of α Orionis as compared with other giant stars of lower absolute magnitude. This is no doubt due to the lower temperature of α Orionis, which affects lines of this character greatly. At the same time, the very low density of the brightest giant stars favors the prominence of the enhanced lines due to the ionized element, and leads to remarkable differences of intensity when such stars are compared with dwarfs, or in less degree with other giant stars of lower luminosity. These characteristics are now being utilized in a study of the absolute magnitudes of about 180 M-type stars of the giant class.

The great increase during recent years in our knowledge of regularities in spectra and their physical significance has provided a basis for the interpretation of the behavior of lines in stellar spectra which was previously lacking. Moreover, the investigations of Strömberg and others have shown that the motion of the sun as derived from stars of different spectral types and different absolute magnitudes can no longer be regarded as a constant. It therefore seems desirable to undertake certain further investigations of the correlation of the behavior of spectral lines with absolute magnitude, partly because the knowledge of physical interpretation should aid in the selection of critical lines in addition to those now in use, and partly because the recognition of the relative character of the solar motion should increase the precision of determination of mean parallax and absolute magnitude. Particularly in the case of giant stars is a marked gain in accuracy to be expected.

The registering microphotometer has proved of especial value in the study of the relative intensities of the lines in stellar spectra used in determinations of absolute magnitude. Curves of the spectra of giant and dwarf stars of the various types, made with this instrument by Miss Ware, permit rapid and accurate studies of the principal differences.

Determinations of the relative intensities of the lines already used in the absolute magnitude work and of several new lines have been continued throughout the year. The completion of the computations based on values of the solar motion appropriate to the different spectral types will add a large number of stars to those with luminosities determined by the spectroscopic method.

ABSOLUTE MAGNITUDES OF LONG-PERIOD VARIABLES.

Merrill and Strömberg have carried out an investigation of the mean absolute magnitudes of the long-period variable stars of types Me and Se, using radial velocities, proper motions, and the few trigonometric parallaxes at present available. Their conclusion is that the absolute magnitude at maximum of light of a typical variable of either class is about zero, stars of the earlier subdivisions of type Me being brighter than those of the later subdivisions. The diameters of stars similar to α Ceti are probably 100 or 200 times that of the sun.

SPACE-VELOCITIES OF LONG-PERIOD VARIABLES.

The results obtained from the parallaxes of Me variable stars have been used by Strömberg and Merrill for a determination of the motions in space of 77 stars with known radial velocities and proper motions. The ellipsoids representing the distribution of velocities have been derived for two groups of stars and are found to fall in the general sequence of velocity-groups discovered by Strömberg.

THE SPECTRUM OF α CETI.

The study of the spectrum of this important long-period variable star has been continued by Joy with interesting results. The peculiar asymmetry of the spectrum near minimum of light led Joy to suggest to Dr. Aitken of the Lick Observatory an examination of the star for possible duplicity. On October 19 Dr. Aitken found a companion at a distance of $0''.9$ from the variable in the position angle indicated by the spectroscopic observations. This discovery will go far toward explaining the spectral peculiarities near minimum, as well as the discordant values of the trigonometric parallax found by several observers. It will, moreover, necessitate the application of a correction to all observations of the light at minimum. The radial-velocity curve, as derived from the absorption lines, shows a range of 12 km./sec. and has its maximum at the time of maximum of light.

PRESSURES AND CONVECTION CURRENTS IN STELLAR ATMOSPHERES.

St. John and Adams have applied to the spectra of some of the brighter stars the methods used by St. John and Babcock in their study of the spectrum of the sun. The material employed consists of spectrograms of Sirius, Procyon, and Arcturus, taken about 15 years ago at the coudé focus of the 60-inch reflector with a prismatic spectrograph, which gave a linear dispersion of 1.4 Å to the millimeter at $\lambda 4300$.

The mean displacements of groups of lines for which the pressure-coefficients differ considerably in the laboratory were first investigated, and the results were found to agree in indicating pressures which are very low and comparable with that in the sun. The relative displacements of the arc and the enhanced lines were then examined and compared with the relative displacements of lines which, in the solar atmosphere, are known to originate at

widely different levels. The agreement is such as to afford strong evidence that the cause producing the relative displacements is the same for both classes of lines. The presence of convection currents of moderate intensity in the atmospheres of these stars, upward at low levels and downward at high levels, is indicated by these results.

The values of the relative displacements in the spectra of these stars and the velocities corresponding to them are given in the accompanying table for two groups of arc lines. The group designated as high level includes lines which are known from eclipse results to reach an elevation of 600 km. or more in the sun's atmosphere; the low-level group, lines which are below 600 km. The values for corresponding lines in the solar spectrum are added for comparison. The surface temperatures are from the results of Seares.

	No. of Lines.		High minus low.	Equivalent velocity.	Temperatures.
	High level.	Low level.			
			A	km./sec.	°
Sirius.....	64	113	+0.018	+1.20	8,800
Procyon.....	73	222	+0.010	+0.67	6,400
Arcturus.....	80	666	+0.005	+0.34	3,900
Sun.....	.....	.....	+0.003	+0.20	5,800

The results point to a progressive increase in the relative displacements and the equivalent velocities with increase in surface temperature in these stars, a relationship which appears quite reasonable. The displacement for Arcturus, larger than for sun, may well be due to the giant character of Arcturus and the much greater extent of atmosphere involved. Evidence in favor of Campbell's interpretation of the K term in B-type stars is afforded by these results, and the existence of convection currents may also aid in the explanation of the relative displacements of emission and absorption lines in the spectra of Me variables.

DYNAMICAL PARALLAXES.

Dr. Russell has continued his investigations on dynamical parallaxes and stellar masses. The results from trigonometric parallaxes are found to confirm those derived last year from spectroscopic parallaxes, except in the case of the A-type stars. For these the spectroscopic parallaxes are about 20 per cent larger. This work is being continued.

MISCELLANEOUS INVESTIGATIONS.

Humason has continued his classification of the spectra of faint stars in the Selected Areas with magnitudes between 11 and 12 on the photographic scale. Eleven areas have been observed this year with the slitless spectrograph on the 60-inch reflector.

The small slit spectrograph at the Cassegrain focus of the 100-inch reflector has been used by Humason and Joy for observations of the spectra of faint stars. These have included stars of large proper motion, a few stars in globular clusters, and certain short-period variables. The average visual magnitude of the stars observed is 11.1.

Merrill and Humason have continued their investigation with slit spectrographs of the 80 early-type stars with bright hydrogen lines which have been

discovered by them on photographs taken with an objective prism. Many of these stars have spectral peculiarities of exceptional interest.

Dr. Vanderlinden has used the 10-inch photographic telescope with a 6° objective prism for the spectra of faint stars. Ten plates, 14 by 17 inches in size, with a minimum exposure of 4 hours, have been obtained in regions near $\pm 30^\circ$ of galactic latitude. Direct photographs of these regions were made at the same time and a comparison of the plates for the characteristics of the faint stars and nebulae may furnish results of interest.

A small spectrograph at the primary focus of the 60-inch reflector has been used by Sanford for the study of a few objects. A spectrogram of N. G. C. 6995 shows a nebular spectrum of bright lines, the strongest of which is $\lambda 3726$. The radial velocity is about $+100$ km./sec.

TWENTY-FOOT INTERFEROMETER.

Measures with the interferometer made during the year have not their usual value because of the prevalence of poor seeing. Observations of the stars previously measured have been continued by Pease, without notable changes in the results. The fringes of Betelgeuse disappeared for mirror separations of 11 to 12 feet, which is less than that in preceding years, but at the same time the visibility of the fringes of the early-type comparison star was far below normal because of unfavorable atmospheric conditions.

Larger mirrors, permitting the use of apertures 7.5 inches square, were installed in December, but owing to poor observing conditions and other matters which interfered with the observing program, the fringes were not seen until July. The adjustment of the mirrors is now made by means of small motors, thus avoiding the necessity of an assistant stationed at the upper end of the tube.

RADIOMETRIC OBSERVATIONS OF STARS.

Measurements of stellar radiation with the vacuum thermo-couple and photographic registering device have been continued regularly by Pettit and Nicholson with the 100-inch telescope. During the last 10 months 362 sets of observations have been obtained. A large comparator, constructed in the instrument shop for the measurement of the photographs, has proved of great value in these investigations.

The observations have all been made with a rock-salt window on the thermo-couple cell, with the purpose of studying the variation of long-wave radiation with spectral type. A screen of microscope cover-glass makes it possible to separate and measure radiations of wave-length greater than 6μ . The results show a continuous increase in the amount of radiation with spectral type, ranging from zero for stars earlier than A5 to about 6 per cent for stars of type M7e. The amount of radiation between 1.3μ and 6μ is about 15 per cent for stars of type B, and increases continuously with spectral type until it becomes 75 per cent for those of type M7e.

Among the variables of long period are many for which observations have been made at two maxima and minima of light. These agree in showing that while the light may vary by a factor of many thousands, the total radiation changes but two or three times in amount. The star X Cygni of this type of spectrum has again been observed at its minimum of the thirteenth magnitude. The results confirm those made previously, in showing a variation of only 1.7 in the total radiation for a light variation of 1,320 fold.

Algol was followed continuously through its minimum on November 16, and 39 sets of observations were obtained of the radiation from Algol and comparison stars. They confirm spectroscopic results in indicating that the eclipsing companion is of early spectral type.

For the purpose of calibrating the thermo-couple in absolute units, observations have been made on the radiation from standard lamps and the sun. These show that the radiation from a star of radiometric magnitude zero at the zenith on Mount Wilson is 17×15^{-12} cal/sq. cm. min. On this scale the radiation received through the earth's atmosphere at the zenith is 25×10^{-12} for Capella and 77×10^{-12} for Betelgeuse.

MEASUREMENTS OF STELLAR ENERGY SPECTRA WITH THE RADIOMETER.

In October 1923 successful measurements of the energy curves of stellar spectra were carried out with a radiometer and the 100-inch telescope by Dr. Abbot, Director of the Astrophysical Observatory of the Smithsonian Institution.

The apparatus consisted of a special radiometer of high sensitiveness, designed by Dr. E. F. Nichols, used in conjunction with a collimating system and spectroscope in the constant temperature room at the coudé focus of the large reflector. Only one vane of the radiometer was used in the observations. The deflections were measured by a mirror with an area of less than 0.2 sq. mm. attached to the radiometer suspension, which threw a spot of light upon a scale at a distance of 5 meters. A complete observation consisted of a series of 15 settings made in the spectral region 0.437μ to 2.224μ and repeated in the reverse order. Not all of the stars gave measurable deflections over the entire interval.

The stars observed were β Orionis, α Lyræ, α Canis Majoris, α Canis Minoris, α Aurigæ, α Tauri, β Pegasi, α Orionis, and α Herculis. The largest deflections of about 50 mm. were given by α Orionis. The measures were reduced by the aid of observations of the sun with the same apparatus, and the application of the data gathered by the Smithsonian observers through many years of study of the solar constant at Mount Wilson. In this way the stellar energy curves on a normal scale were derived, corrected for the effect of the earth's atmosphere.

Since the measures in the regions of wave-length shorter than 0.55μ were necessarily of low weight, they were supplemented by the photometric results of other observers, and satisfactory agreement was found in overlapping portions of the spectra. The combined results were then represented graphically and compared with the theoretical energy curve of a black body to determine the absolute temperatures best agreeing with the measures. In most cases the accordance between these temperatures and the observations is fairly good. A double energy maximum is found in the spectrum of Rigel, and in the case of α Lyræ, α Canis Minoris, α Aurigæ, and α Herculis there are certain irregularities, some of which at least are probably due to the atmospheric conditions at the time of observation.

Dr. Abbot has calculated the diameters of black bodies which at these temperatures would send to the earth the observed amounts of radiation. The values agree with those obtained with the interferometer, or from Russell's theoretical considerations in the case of stars of solar type fall below them for the hot stars, and are larger in the case of giant K and M stars. The discrepancy may be due to the temperatures employed, or to differences in

their radiation from that of black bodies. The order of magnitude, however, is sufficiently accordant to add strong confirmation to the prevailing views of stellar constitution.

The investigation is being continued by Dr. Abbot with instruments of increased sensitiveness. The possibility of observing fainter stars and securing more accurate determinations of the energy curves throughout the spectrum affords promise of results of great interest and wide application.

STATISTICAL INVESTIGATIONS OF STELLAR DISTRIBUTION AND STELLAR MOTIONS.

THE LUMINOSITY AND DENSITY FUNCTIONS.

The study of the luminosity function by Seares described in the preceding report showed that the frequencies of absolute magnitudes in a given volume of space can not be represented by a Gaussian error curve. A continuation of the investigation indicates that the frequencies increase steadily beyond the maximum found by Kapteyn and van Rhijn at $M=7.7$, at least as far as $M=15$. This is clearly the case for the intrinsically faint stars near the sun. If the result holds for other regions of space as well, the total number of stars of low luminosity must be enormous.

The relative densities remain unchanged, but the total density is greatly increased, the number of stars per cubic parsec to the fifteenth absolute magnitude being about twice the number hitherto adopted for all absolute magnitudes.

The quadratic exponential function used by Kapteyn to represent the distribution of stellar density seems to be valid, for specified values of the coefficients, throughout a range of about 1.6 in the logarithm of the distances. Although the coefficients vary with the distance, the range within which a given set of values is applicable is large enough for a satisfactory treatment of many problems with a density function of the quadratic exponential form.

FREQUENCY FUNCTION FOR TANGENTIAL VELOCITY.

The investigations of the luminosity function required a study of the distribution of the tangential velocities of the stars, uncorrected for solar motion. Adams, Strömberg, and Joy have shown that the logarithms of the corrected space velocities are well represented by a Gaussian error curve. With this as a basis, Seares finds that the logarithms of tangential velocities greater than about one-third the geometrical mean velocity are also well represented by an error curve. For the smaller velocities general considerations show that the frequencies are sensibly proportional to the velocity itself.

MEAN PARALLAXES OF STARS OF ZERO PROPER MOTION.

Kapteyn's mean parallax formula has the defect that it gives a zero value of the parallax for stars of zero proper motion. The formula is empirical, and was derived from stars having moderate and large proper motions; but its form is that corresponding to luminosity and density functions of the well-known type, combined with a Gaussian distribution of the logarithms of the tangential velocity. The use of the frequency function for small velocities described above leads, however, to a very simple analytical expression, correct in form, for the mean parallaxes of stars of zero proper motion. This gives results substantially in agreement with the values found by van Rhijn.

SOLAR MOTION AND MEAN PARALLAXES OF STARS OF A GIVEN MAGNITUDE.

The mean parallaxes of stars of a given magnitude (all proper motions together) calculated from secular parallaxes with a constant solar speed do not agree with those found from the frequency functions for luminosity and density. The inference, in accordance with a result found by Strömberg, is that the sun's motion depends upon the brightness of the reference stars. Seares has used the disagreement to determine the solar motion as a function of apparent and absolute magnitude. The numerical agreement with Strömberg's provisional result is excellent, and indicates that the relation found is at least substantially correct. With the aid of this relation, the mean parallaxes of the stars of different apparent magnitudes have been recalculated from the secular parallaxes. The revised values for the brightest stars are larger by about one-third than those hitherto adopted, while those of the twelfth and thirteenth magnitudes are about two-thirds the earlier values.

ASYMMETRY IN THE DISTRIBUTION OF COSMIC VELOCITIES.

In continuation of his study of the asymmetry in stellar motions, Strömberg has found that stars of the Ursa Major and Taurus groups, as well as other stars of types A, F, G, K, and M, the bright-line nebulae, long-period variables, short-period variables, and stars showing an extreme dispersion in velocity, form a sequence in which the group motion changes in a regular way with the internal velocity-dispersion. The relationship between group-motion and dispersion along an axis parallel to the group-motion may be expressed by the equation of a parabola. The distribution of stellar velocities can therefore be represented as the product of two distribution functions F_1 and F_2 , symmetrical about two different centers. The sun's velocity with reference to the center of F_1 is 13.9 km/sec. directed toward the point $\alpha = 262^\circ$, $\delta = +15^\circ$. The sun's velocity relative to F_2 seems to be the same as that derived from globular star clusters and non-galactic nebulae, and is about 300 to 400 km./sec. toward $\alpha = 323^\circ$, $\delta = +60^\circ$.

These results indicate that the distribution of stellar motions is determined by two relationships, one with the local system of stars, and the other with a very large cosmical system. The first must be due to the conditions of origin, modified by internal gravitational attractions. The nature of the second connection is more uncertain. It may arise from the influence of an immense field of stars or of cosmical dust through which the local system is traveling, or, as suggested by Strömberg in last year's report, it may be due to a property of space itself or of a stationary medium filling space, which exerts a restricting effect upon cosmic velocities.

LABORATORY INVESTIGATIONS.

The ultra-violet spectra of vanadium and chromium in the regions $\lambda 2340$ to $\lambda 3181$ and $\lambda 2362$ to $\lambda 3527$, respectively, both beyond the limits reached in previous work, have been studied by King in the furnace, arc, and spark. This work has included the classification of 1,107 lines according to the temperatures at which they appear and their changes with increasing temperature, and the determination of new or improved wave-lengths for 191 lines. Since the intensity of the emission spectrum from the furnace falls off rapidly in the ultra-violet, the absorption spectrum produced by a plug in the tube or by a high-power tungsten lamp behind the furnace has again been used to

extend the spectrum toward the violet; 88 lines of vanadium and 158 of chromium have thus been added to the number obtained in emission. The "multiplet" grouping of lines which show similar response to temperature changes is evident in the case of both elements, thus illustrating the usefulness of the classification as an aid in the search for regularities in these spectra.

The significance of differences in the spectra of an element produced by various light-sources is becoming clearer, and the phenomena are finding steadily increasing astrophysical application. A study of the spark spectrum of titanium, supplementing the investigation of furnace lines reported last year, shows the full development of the ionization which begins at the furnace temperatures and appears more strongly in the arc. The variations possible in each of the three sources reveal intermediate stages in the radiation. The spark spectra of vanadium and chromium have also been compared with those of the furnace and arc in a study of the development of the more sensitive lines of the ionized atom and the degree to which they may be classed as "ultimate lines." A still higher stage of spark radiation has been reached by photographing the spectrum of the iron spark produced by very powerful condenser discharges. This shows a close approach to complete ionization, the lines of the neutral atom being suppressed.

Other furnace studies by King have included the high-pressure spectrum of calcium for suspected enhanced lines, the ultra-violet spectrum of thallium, tests of the absorption of mercury lines, and the line and band spectra of zirconium. A series of photographs of zirconium in the ultra-violet supplement the extensive material already in hand for the study of rare-earth spectra now being carried on with the aid of Miss Carter. Zirconium is found to have a high-temperature spectrum, most of the lines being produced by the ionized atom. The rich band spectrum in the yellow and red has also been found to require relatively high temperatures, its initial appearance being at about 2,400° C. This result has been used by Merrill in estimating the temperature of S-type stars.

Anderson has continued his work with the vacuum spark, giving especial attention to the spectra of oxygen and nitrogen, both of which are well developed under suitable conditions.

The vacuum spark spectra of thallium, gallium, and indium have been investigated by Mr. J. A. Carroll.

HIGH-CURRENT ARC.

Preliminary experiments have been made by King with direct current arcs of high amperage. The electric furnace has been temporarily adapted to the purpose while special apparatus is being constructed, and arcs between carbon electrodes loaded with iron, chromium, or calcium have been operated at about 1,000 amperes with a potential of about 100 volts. Metallic terminals can also be used for brief runs. The useful feature of the high-current arc is that, while the ionization does not compete with that of the spark, the excitation of the neutral atom exceeds that of the low-current arc. The result is a predominance of the high-temperature lines, with relative intensities approaching those in the solar spectrum. The high-current arc is thus adapted to the study of those classes of lines which are absent from the furnace and faint in the low-current arc. Its intense brightness will permit the photography of difficult regions of the infra-red and ultra-violet with high dispersion. The widening of lines, often unsymmetrical, can be governed by the amount of

material used. With heavy charges of metal it is very pronounced. Since oxygen, hydrogen, and other gases can be introduced through one of the electrodes into the arc, very intense banded spectra of compounds formed in the envelope of the arc may be expected from this source.

ELECTRICALLY EXPLODED WIRES.

A new 10-kw. 100,000-volt transformer with synchronous rectifier was received in December 1923, and the work of assembling the high-voltage condenser was undertaken by Anderson without delay. About 25 of the 218 glass plates received from the manufacturers were broken in transit, and a number of others were rejected because of air bubbles in the glass and other obvious defects. Approximately 175 plates were subjected to a preliminary voltage test at 90,000 volts, a single pair of plates being tested at a time. The plates which passed this test were assembled in heavy wooden frames built to support the condenser. The completed condenser consists of 160 plates, having a capacity of a little more than 0.6 micro farad, and is operated at potentials not exceeding 60,000 volts. Even under these conditions a few plates have broken, apparently because of internal surges, causing abnormally high potentials to develop across particular pairs of plates. At 55,000 volts the condenser, in its present state, gives a maximum discharge current of 40,000 amperes, and hence a rate of energy development in a wire explosion or spark 16 times as rapid as that of the old condenser.

A study of electrically exploded wires has been made by Sinclair Smith with the new condenser as the chief source of energy, with the object of finding how the spectrum of an exploded wire varies during the very brief interval the phenomenon lasts. For comparison, the old condenser has also been used under similar conditions. To record the results a special spectrograph was constructed in which a very narrow spectrum moves over the photographic film perpendicularly to the length of the spectrum, with a speed of about 500 meters per second. Since the width of the spectrum is 0.5 mm. it moves its own width in a millionth of a second and, consequently, changes taking place in an interval of this order can be studied. The dispersion employed is that given by a concave grating having 15,000 lines per inch and a focal distance of 65 cm. and amounts to almost exactly 25 Å per millimeter. The light from an exploded wire is bright enough to yield fully exposed spectrograms under these extreme conditions.

At the beginning of an explosion, whether taking place in the open air or in a partially inclosed space, the spectrum is continuous, with the arc lines of the metal exploded appearing as absorption lines. With the old condenser and an open-air explosion, the duration of the continuous spectrum is very short, of the order of $1/200,000$ second; in this phase such pronounced enhanced lines as $\lambda 4481$ of magnesium show faintly as bright lines. With the more powerful discharge of the new condenser, the continuous phase lasts very much longer, the spectrum is brighter, and such lines as $\lambda 4481$ show clearly as absorption lines; moreover, the spectrum is essentially the same, whether the wire is exploded in the open air or is partially confined, while with the old condenser an open-air explosion gives chiefly a bright-line spectrum. This shows that at the temperatures reached in the more powerful discharge, metallic vapors at a pressure only slightly above one atmosphere emit essentially as a black body. The depth of the layers of vapor experimented with was seldom more than 6 cm. The maximum temperature in the vapor proper exceeded $20,000^{\circ}\text{C}.$, but could hardly have reached $30,000^{\circ}\text{C}.$

Rough comparative measurements of the conductivity of metallic vapors at these high temperatures were also made by Smith. The best conductor was iron vapor, the second best lithium, while the poorest, in order, were copper, silver, and gold. Nickel, though in other respects so much like iron, is relatively a poor conductor at these temperatures.

THE ZEEMAN EFFECT.

Further studies of the Zeeman effect by Babcock, especially for vanadium, have considerably improved the agreement between calculation and observation, thereby accounting for certain small systematic differences of previously unknown origin. In so far as the quantum theory has been developed to explain the Zeeman effect, there remains no inconsistency with our observations; but many observed separations await extensions of the theory, and many predictions are as yet unobserved on account of the enormous resolving power required to show them. The importance of observations of the Zeeman effect is attested by their usefulness in the analysis of the complicated spectra of iron and vanadium. The suggestions of Dr. Russell have proved invaluable in the expansion of this work.

STANDARDS OF WAVE-LENGTH.

The extended measures of wave-length made here in recent years have been based on the adopted system of secondary standards. Since these standards depend on three accordant determinations of iron-arc wave-length in terms of the primary standard and have been intercompared, it has hitherto seemed likely that they were free from serious systematic errors. With the more extensive use of neon lines as standards, however, small discrepancies began to appear, and during the last 5 years numerous instances have arisen in the comparison of iron lines with those of neon, mercury, or cadmium, in which a small decrease in the adopted values of the secondary standards would have increased the consistency of the results. The evidence now accumulated is such as to justify a new scrutiny of the secondary standards. The Bureau of Standards has recently published the results of such an investigation, the University of Chicago is at work on the same problem, and Babcock at this Observatory has given the matter much attention. If satisfactory accordance can be attained, the way will be cleared for a complete revision of the system of standards. The largest correction which now seems to be required is only about one part in one million, but modern methods require about five times this accuracy in the measurement of wave-lengths. The new observations involve comparisons of wave-lengths of iron, neon, and cadmium lines, with all the refinements of equipment and technique that can profitably be applied. The interference method is used exclusively, on account of the great range of wave-lengths to be covered.

Attention thus far has been directed mainly to the red lines of iron, for which the observations are now nearly completed. The results confirm those of other observers in requiring a reduction of the adopted standard values, but the indicated correction is appreciably greater than that found at the Bureau of Standards. Incomplete measurements in the green are in close agreement with those of other observers.

This exacting observational work is much facilitated by the new concave grating. Without it measurements in the infra-red would be practically

impossible, because of the exposures required. Another useful aid is a new concave projecting mirror made by Dalton, 16 inches in diameter and of 18 inches focal length. This gives a great enlargement of the image of the arc on the etalon, and still permits the observation of numerous interference rings when necessary.

Although the secondary standards now appear to be subject to small errors, our extended measurements on solar and arc wave-lengths are not affected because precautions were taken to use differential methods only.

INVESTIGATIONS OF THERMO-COUPLES.

Pettit has studied the behavior of thermo-couples and thermopiles under a variety of laboratory conditions. From observations of the effects of temperature, it appears that the corrections to stellar observations may in some cases amount to one or two hundredths of a magnitude.

In the usual form of thermopile the elements are connected in series. By connecting the elements in a series-parallel combination the resistance can be adjusted to give the maximum sensitivity for any galvanometer. Such a thermopile was made for ultra-violet spectroscopy and, when connected to a d'Arsonval galvanometer, was found to give deflections several times greater than those obtained previously, when the same measurement was made with other thermopiles used in combination with a Thompson galvanometer.

A double slit has been devised for the registering device of the galvanometer which makes it possible to set up this part of the apparatus in a brightly illuminated room without fogging the photographic plate upon which the energy curve is traced.

REGULARITIES IN SPECTRA.

Dr. Russell has been engaged mainly in investigations relating to the analysis and physical interpretation of spectra and their astrophysical applications. Nearly 1,100 lines have been classified in the arc spectrum of titanium and more than 300 in the spark spectrum. Very few lines of any importance remain unclassified in the arc spectrum or in that of the spark as far as $\lambda 3300$. For the spark most of the lines are classified as far as $\lambda 2800$, beyond which the data are very imperfect and new measures are being made.

The arc spectrum contains well-developed multiplets belonging to singlet, triplet, and quintet systems, with numerous inter-combinations. The inner-quantum combination rules and Landé's rules for the Zeeman effect are strictly followed. The ordinary azimuthal exclusion principle is supplemented by a division of the terms into two sets, such that a term of one set combines only with terms of the other set, but, barring certain exceptions among the quintets, with all terms of the other set for which the azimuth quantum differs by 0 or ± 1 . In the triplet system, which is the most extensive, terms of types s, p, d, f, g, h, and i have been recognized. The lowest energy level, or normal state of the atom, is a triple f-term; the next lowest, a quintet f-term; and the next, a single d-term. Only one series, of the ordinary kind, has been found. This is composed of s-terms, and its limit indicates an ionization potential of 6.5 volts.

The principal resonance lines are at $\lambda\lambda 5210$, 5193, 5174, corresponding to a resonance potential of 2.39 volts. Subordinate resonance lines (inter-system) occur at $\lambda\lambda 6360$, 6325, 6297, etc., with a resonance potential of 1.98 volts.

The spark spectrum contains extensive systems of pairs and of quartets. The exclusion rules are as described above, except that a number of combinations occur in which the azimuth quantum changes by ± 2 . The lowest levels are two quartets from the f-level very close together, and the next is a doublet f. The principal resonance potential, 3.67 volts, corresponds to an ultra-violet multiplet including $\lambda\lambda 3384, 3373, 3361, 3349$. The strong chromospheric lines at $\lambda\lambda 3761, 3759, 3685$ arise from the lowest doublet level. No series have yet been found, and the ionization potential remains unknown.

In both arc and spark spectra, the energy level of origin of a line is very closely correlated with the temperature classification used by King. Ultimate arc lines, which are those originating in the lowest level, are of Class I; ultimate spark lines of Class III; while the lines arising from higher levels are of successively higher temperature. This has been of great value in the analysis of the spectrum. Unpublished data by Babcock, and measures in the extreme ultra-violet, kindly communicated by Dr. Kiess of the Bureau of Standards, have also been of much value.

Dr. Russell has compiled from various sources a list of over 1,800 lines of present or probable astrophysical interest, for which the series relations and energy-levels of origin are known. The list includes the most important lines in the arc spectra of 37 elements, and in the spark spectra of 15.

Doctors Meggers, Keiss, and Walters have generously permitted the use of much unpublished material from the Bureau of Standards. These data will be of much importance in the interpretation of solar and stellar spectra. For example, the ultimate lines are greatly strengthened in sun-spots and in dwarf stars for all elements which have been examined. Again, among lines of the same multiplet, and therefore presumably affected alike by temperature and pressure, those of intensity greater than 8 on Rowland's scale are very little affected in passing from the photospheric to the spot spectrum; while lines of intensity 1 or less are greatly affected. This indicates for the strong lines a nearly saturated absorption, so that a large change in the number of absorbing atoms makes little difference in the intensity of the line. All but the faintest lines of iron are practically saturated, and the strongest lines of titanium, but not the weaker ones; while even the ultimate arc lines of vanadium and scandium are conspicuously unsaturated. This indicates that iron is much more abundant in the sun than titanium, while vanadium and scandium are present in but small proportions. Further study, both of laboratory and solar intensities, is promising. Finally, the possibility of predicting, by Landé's method, the Zeeman separations for hundreds of lines, including many faint ones hard to observe in the laboratory, should be of value in the study of solar magnetic fields.

When about a dozen more spectra (mainly enhanced) have been analyzed, it should be possible to place stellar spectroscopy on a rational basis, in which the physical significance and energy relations of all important lines are taken into account. Almost all these spectra are now under discussion by various investigators. The spark spectrum of iron, which is one of the most important, is being attacked cooperatively by Merrill and several members of the Observatory staff.

THE VELOCITY OF LIGHT.

The unfavorable conditions of transparency which prevailed during the later summer months of 1923, due to smoke from forest fires and an exceptional amount of dust and haze, made it advisable to begin observations this year at an earlier date. Dr. Michelson returned to Pasadena early in June and the apparatus both at Mount Wilson and on the San Antonio ridge was prepared and adjusted. Through the kindness of Mr. E. A. Sperry, a powerful arc lamp of his design was loaned for the investigation, and the very first tests showed that with this source of illumination ample light would be available, even under average conditions of transparency. The permanency of the adjustments of the instruments at the distant station has proved to be most satisfactory and a troublesome source of delay is thus avoided.

Dr. Michelson is now engaged in further tests of the rotating mirror and the design and construction of apparatus for measuring its speed. The modification of the Foucault method, described in last year's report, will probably be adopted for use in the definitive measures since the amount of light seems to be sufficient for the purpose. Two pendulums of accurately known vibration period have been loaned to Dr. Michelson by the United States Coast and Geodetic Survey and should facilitate greatly the measurement of the speed of the mirror. Mr. Donald G. Pheley of the Survey has used these pendulums in a careful study of the acceleration of gravity at the station on Mount Wilson and at the California Institute of Technology.

Major Stephenson of the Corps of Engineers of the United States Army will undertake, in cooperation with Dr. Michelson, photometric measures of the light transmitted through air-paths of varying length.

A SOLAR LABORATORY IN PASADENA.

As explained in the introduction, Dr. Hale has provided for the erection of a small Solar Laboratory in Pasadena, where most of his work will be done in the future. The laboratory, which is being built of reinforced concrete by the Construction Division under the supervision of George D. Jones, is situated near the southern boundary of Pasadena on a lot 95 feet wide and 300 feet deep, immediately adjoining the extensive grounds of the Henry E. Huntington Library and Art Gallery, from which it was purchased. Its outside dimensions are 21 by 49 feet, with a wing below ground containing dynamos, transformers, and the heating and ventilating plant. The tower at the south end, 21 feet square, carries the cœlost at its summit, 30 feet from the ground level, covered by a dome 14 feet in diameter. In the center of the tower, descending from the spectrograph room in the basement, is a well 10 feet in diameter and 78 feet 6 inches deep. In this will be mounted a composite instrument, comprising a spectrograph with a collimator of 75-foot focal length, and cameras of 30-foot and 75-foot focal length, which can also be used as a spectroheliograph; a 30-foot reflecting spectroheliograph; and a 13-foot combined spectroheliograph and spectrohelioscope. By the use of suitable systems of mirrors and lenses, the diameter of the solar image formed by the cœlost telescope can be made 0.5 inch, 2 inches, 6.5 inches, or 16.5 inches. The spectrograph room, which contains a photographic dark room at the south end, opens on the north into a laboratory 17 by 18 feet, with which it forms a continuous room. North of the laboratory is a small instrument shop, 10 by 15 feet. Above, on the main floor, is a library and study 18 by 27 feet, while the two upper floors of the tower will be used for various purposes. In one of them a special tank for vortex experiments has been provided.

The selection of the site for the Solar Laboratory was based upon a long series of telescopic tests carried on by Dr. Hale throughout the winter. In the valley the sky near the sun is much brighter than on Mount Wilson, and this will interfere with some classes of work, especially in the violet region. As for the seeing, it is probable that the best definition in the valley will be inferior to that on the mountain during the early morning hours. At higher altitudes of the sun, however, it appears that the advantage in definition will sometimes lie with the valley site, because of the absence of the convection currents that ascend the heated slopes of the mountain. The number of clear days in the year will be much smaller in Pasadena than on Mount Wilson, because of the prevalence of low fogs at certain seasons.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

Two of the larger pieces of work in this department, carried on by Pease, Nichols, and H. S. Kinney, have been the design of the apparatus for the National Academy of Sciences and of the instruments for the Solar Laboratory of Mr. Hale. Two cœlostats and auxiliary mirrors, one for use in the physical laboratory and the other in conjunction with the registering microphotometer, have also been worked out in detail. Additional drawings have included a projection apparatus for solar photographs, a modified thermocouple spectrograph, standard lens cells, much miscellaneous apparatus for the 60-inch and 100-inch reflectors, and many charts and diagrams for the publications of the Observatory.

OPTICAL SHOP.

The optical work of the year has included the construction by W. L. Kinney and Dalton of 10 plane mirrors, ranging in size from 6 to 19 inches in diameter, several simple lenses, 2 small achromatic lenses, 3 concave mirrors, 11 small quartz prisms, several plane-parallel plates of rock salt, quartz, and fluorite, and a large number of speculum plates for diffraction gratings. Two large prisms have been locally refigured by Kinney. Several of the plane mirrors are of pyrex glass; two of these with diameters of 15 and 19 inches replacing the ordinary glass mirrors in the 150-foot tower telescope. A concave mirror of 16-inch aperture and 18 inches focal length was figured by Dalton for laboratory use.

INSTRUMENT SHOP.

Nearly 25 per cent of the working time of the instrument shop during the past 10 months has been devoted to the completion and erection of the instruments for the National Academy of Sciences. Other large pieces of construction in the shop, under the direction of A. F. Ayers, have been two 12-inch cœlostats with auxiliary mirror mountings, two small driving clocks, the large spectrograph for use at the coudé focus of the 100-inch reflector, an 8 by 18-inch comparator for measuring radiometric curves, apparatus for the Solar Laboratory, new tools and grinding machines for the optical shop, and a motor-driven adjustment for the 20-foot interferometer. The work has included the construction of many small instruments, and repairs to the equipment on Mount Wilson and in Pasadena have been carried on as usual. Comparatively little work has been done on the 50-foot interferometer in the instrument shop, since the mechanical part is now in advance of the optical work required for the completion of this telescope.

GENERAL CONSTRUCTION, MAINTENANCE, AND TRANSPORTATION.

The transportation and erection of the apparatus intended for use at the total eclipse of September 10, 1923, was carried out by the Construction Division under the superintendence of George D. Jones. Several members of the force of the instrument shop shared in the erection of the instruments, and the material was all transported in the motor trucks of the Observatory.

During the present summer the construction of the large pit and building for the Solar Laboratory has been the principal new undertaking; but grading and maintenance of the road on Mount Wilson, painting, and building repairs have been continued as usual.

The power and electrical equipment on Mount Wilson have remained in charge of Merritt Dowd, engineer, and Sidney Jones, assistant engineer. In addition to the maintenance of the power, water, and light services, they have built much new electrical apparatus, including switchboards and switches of various designs. A large steel framework inclosing the clock room and driving mechanism of the 100-inch telescope is also in process of construction by our engineers on Mount Wilson.

The past winter has been characterized by the severest drought experienced for many years in California, and restrictions on the use of electric power and water have been necessitated, both in Pasadena and on Mount Wilson. The reserve supply of water provided by the construction of the large storage reservoir on Mount Wilson two years ago should, however, under normal conditions during the coming winter enable the Observatory to operate without serious difficulty. The very grave nature of the fire risks due to the drought is appreciated fully by the Forest Service and the Observatory, and special cooperative precautions are being undertaken to guard against the outbreak of forest fires.

INVESTIGATIONS IN PROGRESS.

The principal investigations in progress have already been indicated to a large extent in the detailed report of the work of the year. A brief recapitulation of these and of other researches commenced recently will aid in affording a general view of the present scientific activities of the Observatory.

SOLAR RESEARCH.

Direct photography of the sun and observations with the spectroheliograph are being continued regularly with the 60-foot tower telescope, especial attention being given to active areas near sun-spots. The photographs are used for determinations of sun-spot positions, number, and areas, and for studies of flocculi.

The study of sun-spot polarities forms a most important feature of the solar program, the discovery of the law of reversal of sun-spot polarities with the spot cycle making such observations of critical value. With the increase in the number of sun-spots, radiometric measures and photography of the spectrum are being resumed. The experimental work of Dr. Hale, with its application of new methods and new instruments, will contribute in all of these directions.

The spectroscopic investigations in progress include measurements on the international system of solar wave-lengths, both with the grating spectrograph and the interferometer; further studies of the spectrum of the limb of the sun, including both changes of intensity and displacements of the lines;

observations of the solar rotation; photography of the spectrum of the chromosphere; and measures of the ultra-violet radiation of the sun.

NEBULAR AND STELLAR RESEARCH.

The direct photography of nebulae is for the most part confined to objects of especial interest. Observations are being made at frequent intervals on the Andromeda Nebula, N. G. C. 6822, M33, and a few other objects, for the purpose of detecting novae and variable stars, and determining light curves. Photographs of some of the larger spiral nebulae are being secured for comparison with earlier negatives, and considerable attention is being given to dark nebulae.

Other nebular studies include the determination of a magnitude scale and the color indices of the central stars in planetaries, the color equivalents of nuclear condensations in certain spirals, photography of the spectra of a few spiral and bright-line nebulae, and investigations of the law of distribution of material in amorphous non-galactic nebulae by aid of the observed distribution of intensity in the projected images.

Determinations of trigonometric parallax and proper motion are being continued for a selected list of stars. A special study is being made of the proper motions of stars in certain of the globular star clusters.

Photometric investigations now in progress include the determination of the photovisual magnitudes of stars in 43 of the Selected Areas north of -15° ; the colors of stars in the 30° zone of the Selected Areas; a discussion of star counts based on the photographic magnitudes of stars in 139 Selected Areas; and observations and discussions bearing on the relationship of color-index to spectral type and absolute magnitude. For the first two of these investigations the observations have been completed.

In the department of stellar spectroscopy the principal investigations comprise determinations of radial velocity and absolute magnitude for a large number of stars, including those of spectral types F to M in Boss's catalogue, a list of stars of large proper motion, certain variables related to the Cepheids or the Me stars, visual binaries with dynamical parallaxes calculated by Russell, and a revised list of stars in the Selected Areas. Physical studies of the spectra, especially in the case of the M and Me stars and those of early type with bright lines, form a most important part of the work. The determination of the orbits of some of the more interesting spectroscopic binaries is being continued regularly. One of the larger problems toward the solution of which all of the investigations in stellar spectroscopy are planned to contribute is that of a rational system of classification for stellar spectra based upon the physical interpretation of spectral lines in their relation to atomic structure and energy level.

Spectroscopic determinations of absolute magnitude by the methods previously in use are being continued, and the inclusion of new lines selected from considerations of their physical behavior, the application of the registering microphotometer, and the use of additional material bearing on the calculation of mean parallaxes, all promise to contribute toward a gain in the accuracy of the results derived by this method. A special study of the absolute magnitudes of the M-type stars is nearly completed.

The results of the determinations of radial velocity and absolute magnitude are being applied to several problems relating to stellar motions. In particular

a detailed study of the dependence of the solar motion upon spectral type and absolute magnitude is well advanced toward completion.

Measurements by Dr. Abbot with the radiometer of the energy curves of stellar spectra, and by Pettit and Nicholson with the thermo-couple of the radiation from selected regions of the spectrum, form an important part of the program of research. Radiometric measures of the energy received from the surfaces of the planets are yielding valuable information regarding their temperatures and the probable condition of their atmospheres.

LABORATORY RESEARCH.

Several investigations in the laboratory have for their purpose the analysis and physical interpretation of the lines in complex spectra. Temperature classification according to behavior in the electric furnace, critical studies of the Zeeman effect, and the application of such powerful ionizing agencies as the method of electric wire-explosions, the vacuum spark, and the high-current arc are all being utilized to furnish data to aid in this work. A very thorough analysis of the arc spectrum of titanium has been completed by Dr. Russell, and a similar study of the spark spectrum is nearly finished. An analysis of the spark spectrum of iron will be undertaken by several members of the staff in cooperation. Such investigations have astrophysical applications of the most vital character.

Measurements with the interferometer of standards of wave-length both in laboratory sources and in the sun, and the application of the new condenser to the study of the spectra of numerous elements are other outstanding researches in progress.

NUTRITION LABORATORY.¹

FRANCIS G. BENEDICT, DIRECTOR.

As an aftermath of the Great War the interest in nutrition is worldwide. The major problems of the growing of food-materials, the manufacture, purification, preservation, transportation, and local distribution of food-products, and especially the nature of food and the amounts needed in the animal and human economy are paramount, for it is recognized by all physiologists that the proper feeding of the human from birth to old age is indissolubly bound up with his health, growth, and physical, and probably mental efficiency. Immature, poorly nourished children are a liability rather than an asset to any nation. On the basis of simple economy, therefore, and aside from all humanitarian considerations, at least as much care should be given to the feeding and development of children as to the feeding and preparation for exhibit of the prize hog or steer; yet one may frequently find more attention given to the making of a warm mash for a brood of chicks in the barnyard than to the proper cooking of the food for the children in the farmhouse. For the most successful feeding of humans as well as of farm animals a complete knowledge of the nature of foodstuffs, the chemistry of the ingredients, the processes of normal and abnormal digestion, and the use made of the food by the body is most essential. A well-manned and well-equipped chemical laboratory can solve many of these problems, but those pertaining to human digestion, the use of food by the body, the intermediary and end products of digestion, and particularly the energy relationships, require study by trained physiologists, with special methods and equipment. The Nutrition Laboratory is particularly designed for such research. Furthermore, by the utilization of a part of its resources in the development of technique and methods which have been adapted to other laboratories and clinics, the usefulness of this Laboratory has been indirectly extended in the collection of physiological data pertinent to the major problems of nutrition and, specifically, of metabolism and energy.

Nowhere more than in Europe is the importance of these fundamental physiological studies in metabolism recognized. In the spring of 1923 the Director gave lectures in several European universities, thereby presenting our newest techniques to the educational centers in Europe. This has resulted in cementing even more firmly the close ties that have bound this Laboratory to the principal European laboratories and nutrition centers.

International cooperation in nutrition studies was long the dream of Professor W. O. Atwater, the first to establish research in nutrition in America. This idea is gradually winning the interest and approval of physiologists in Europe and America. In furtherance of such cooperation, the Nutrition Laboratory is now in a position to give real service in the solution of some of the problems of the European scientific world. That this cooperation is to a certain extent an accomplished fact is evidenced by the extensive foreign correspondence, the visits of many European scientists to the Laboratory, and the urgent requests of foreign institutions for visits and lectures from members of its staff.

¹ Situated in Boston, Massachusetts.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Howard F. Root has collected a considerable amount of data with regard to the insensible perspiration of normal humans and, in the clinic of Dr. Elliott P. Joslin at the New England Deaconess Hospital, has studied the insensible perspiration of diabetics.

Professor E. G. Ritzman, of the Department of Animal Nutrition of the University of New Hampshire, has continued the cooperative researches on the metabolism of large animals, with particular reference to fasting, subsequent to the establishment of various nutritive levels. The liberal policy of the University of New Hampshire in providing adequate laboratory facilities in a special building and in sharing the expense of this investigation has been maintained by President R. D. Hetzel and Director John C. Kendall. This cooperative enterprise is our largest at present and has been most satisfactory in every way.

Professor Grace MacLeod, of the Department of Nutrition, Teachers College, Columbia University, New York, is continuing research on the metabolism of the white rat, with particular reference to metabolism during growth and with varying environmental temperature.

As a natural consequence of the resumption of foreign tours by the Director and staff members, many foreign investigators have visited the Laboratory during the past year and spent considerable time in discussing problems and even in actual experimental work. The intense efforts of the Central Relief Bureau in Belgium along the lines of nutrition were represented by the most stimulating visits of Professor Paul Héger and Professor A. Slosse of Brussels. Dr. Karl Petrén of Lund was particularly interested in the metabolism in diabetes, and numerous conferences were held with him and Dr. E. P. Joslin.

Dr. Stefan Ederer, from the Laboratory of Professor Hári in Budapest, while in contact with Dr. F. B. Talbot and his metabolism center at the Massachusetts General Hospital, investigated thoroughly the methods of the Nutrition Laboratory in studying metabolism and the nutrition of children. Dr. Ederer rendered us great service in the revision of proof of a German monograph, describing in detail the Laboratory technique.

The recent activities of the Nutrition Laboratory in studying the metabolism of large animals led to visits from Dr. H. Edin, of the Royal Agricultural Experiment Station of Stockholm, and Dr. H. H. Mitchell, of the University of Illinois, at Urbana. A new respiration apparatus of the Nutrition Laboratory design is being constructed at the last-named institution.

Stimulating conferences were held with Professors A. Biedl of Prague, E. V. Anrep of London, Leonard Findlay of Glasgow, Whitridge Davies of Edinburgh, and Renfrew White of New Zealand.

Mrs. C. G. Benedict, as a volunteer associate in the Laboratory, conducted a number of researches on human metabolism as affected by environmental temperature and body-position.

INVESTIGATIONS IN PROGRESS.

Chemistry of the urine of fasting steers.—Owing to the masterful technique of Professor Folin and his associates, the chemistry of the urine of man has been very elaborately studied. Earlier reports of the Nutrition Laboratory have given many data on the chemistry of the urine under the special conditions represented by complete fasting, that is, when the individual was

living upon body-substance. As an important factor in the study of the chemistry of the nutrition of ruminants, and particularly to study the course of the protein metabolism during fasting, Dr. Carpenter has continued his work upon the chemistry of the urine of fasting steers, in conjunction with the cooperative research at the University of New Hampshire. The ruminant, when fasting, changes from a herbivorous animal to a carnivorous animal, and a study of this transition phase supplies most important data and suggestions of vital importance to human physiology. Collections of urine in periods of 24 hours or less have been made with two full-grown steers during two fasts. One fast was 5 days in length, just after the animals came in from pasture; the other was 10 days in length, after a period of undernutrition. There was also a 5-day fast of two young steers. Quantitative determinations of the following constituents were made in the first two fasts: total nitrogen, urea, ammonia, amino acids, creatine, creatinine, hippuric acid, acetone and diacetic acid, β -oxybutyric acid, free and combined phenols, total fixed bases, total organic acids, inorganic sulphate, ethereal sulphates, and neutral sulphur. Some of the nitrogenous compounds mentioned and the acetone bodies were determined in the fast of the young steers. This research has involved the study of the adaptation to steers' urine of the various methods of analysis applied to human urine, as well as an investigation of the proper method of preservation of the material for subsequent analysis. The analyses have been made by Miss D. M. Tibbetts, Mr. P. P. Saponaro, and Mr. E. S. Mills.

An emission calorimeter.—For a number of years a calorimeter has been desired which would be of small mass and low hydrothermal equivalent, and hence subject to practically no heat lag. A small form for use with animals has been mentioned in several of the former reports. This was successfully developed and has been used extensively. The application of this principle to a calorimeter large enough for humans has been slow in accomplishment. As a result of the indefatigable efforts of Mr. V. Coropatchinsky, the apparatus was brought to a successful completion within the past year and many experiments on humans have been made with it.

Direct calorimetry with varying environmental temperature, humidity, and degree of covering.—With the emission calorimeter, which is especially designed for quick and rapid changes in heat-loss, the measurement of the heat lost by rapid removal of clothing has been successfully carried out. Many experiments with a single subject (an artist's model) have been made with varying degrees of covering, from complete nudity to complete protection with several blankets. The rate of heat-loss on disrobing, the temperature of the cooling skin-surface, and the gaseous metabolism were studied simultaneously. These studies were made by Messrs. V. Coropatchinsky, E. L. Fox, H. S. Palmer, and Miss M. D. Finn.

Metabolism as affected by high environmental temperature.—At the request of Dr. E. F. Du Bois, of Bellevue Hospital, New York, an investigation was made of the metabolism of several subjects when submitted to a very high environmental temperature in an apparatus in use at Bellevue Hospital for producing large volumes of dry, hot air. The subject was placed inside of an oiled-silk bag and a strong blast of highly desiccated hot air was blown over the nude body. The changes in temperature of the skin, the changes in the trunk temperature, and the effect upon the gaseous metabolism were studied.

This investigation, which supplements admirably much of our other work on environmental temperature, was carried out in cooperation with Mrs. C. G. Benedict.

Loss from the lungs and skin.—Through the lungs and skin the body is continually losing material which is chiefly water, but in part oxidized organic matter. This loss—the so-called “perspiratio insensibilis”—is studied theoretically in a simple manner by exact weighings of the body from time to time. The Laboratory possesses a balance capable of weighing a human to within a few tenths of a gram. Thus this loss can be determined in relatively short periods, and the influence of environmental temperature, wind velocity, humidity, and degree of clothing can be easily studied. By having the subject breathe through a mouthpiece into a suitable respiration apparatus supplied with oxygen, the loss in weight due solely to the loss through the skin could be obtained. These investigations have been carried out with the cooperation of Mrs. Benedict and Messrs. E. L. Fox and H. S. Palmer.

Metabolism in a prolonged neutral bath.—For handling pronounced mental cases, no therapeutic procedure compares in efficiency with the prolonged neutral bath. The immersion of the body in a bath with a temperature of approximately 96° F. produces no sensation of heat or cold, but only a feeling of relaxation that is most beneficial. It has been argued that possibly this sensation may result in a decrease both in muscular tonus and in the general heat-production and metabolism, and a severe arraignment of present-day methods of determining basal metabolism has been based upon a supposed heat-production to offset loss to a cold environment. In collaboration with Mrs. Benedict, a series of observations was made with four subjects, in which the metabolism was determined before and after immersion in a bath at 36° C. (body-temperature). A preliminary report of the results was given at the National Academy of Sciences and the detailed investigation is shortly to be published.

Influence of body-position and minor muscular movements on metabolism.—In many researches a study is made of the heat-production as a result of muscular work, but some basis of reference is desired to determine the efficiency of the superimposed muscular activity. Whether this basis of reference should be obtained with the subject lying, sitting, or standing is still debatable. Furthermore, it is common custom to determine the basal metabolism when subjects are in the lying position. Information has been much desired regarding the differences in metabolism with these three simple changes in position, as studied with perfected technique and with trained subjects. Furthermore, data as to the influence of minor muscular activity, such as simple movements of the arm or leg, are important in indicating how strict should be the muscular control during basal metabolism experiments. Using a trained subject, Mrs. Benedict has carried out a long series of observations to secure information on these questions, and the details will shortly be published.

Measurement of oxygen required to burn various food-materials.—In problems of dietetics, where a knowledge of the energy or fuel-value of food-materials is important, great difficulty has heretofore been experienced in obtaining data because of the complexity of the apparatus usually employed for these determinations, i. e., a calorimetric bomb with specially constructed thermometers and requiring elaborate computations. Secondly, the complicated

nature of the majority of food-materials of civilized man makes the computation of their fuel-value from the ingredients rather difficult. In burning various food-materials in pure oxygen definite amounts of oxygen are required, and there are mathematical and chemical relationships between the oxygen involved in the combustion and the heat produced. The simple respiration apparatus devised by the Director and Mrs. Benedict has been so modified that it is now possible to measure the amount of oxygen required for the combustion of 1 or 2 grams of previously dried food-material. Such measurement has established the fact that the range of ratios between the amount of oxygen consumed and the actual heat of combustion as determined by a calorimetric bomb is very narrow, and it is therefore believed that for much of the work in nutrition the calorimetric bomb can ultimately be dispensed with. This investigation has been largely in the hands of Mr. E. L. Fox.

Metabolism of large ruminants during fasting.—In the cooperative investigation carried out with Professor E. G. Ritzman, of the Department of Animal Nutrition of the University of New Hampshire, the respiration chamber has been employed in measuring the metabolism of large steers during complete fasting. The apparatus has been somewhat modified, but the chief addition to the technique has been the employment of the new gas-analysis apparatus of Dr. T. M. Carpenter, by means of which the oxygen consumption of these animals can be rapidly determined. With the addition of this apparatus it is now possible to measure the carbon-dioxide production and the oxygen consumption of these steers, and the facilities for collection of excreta and weighing of the feed during the subsequent realimentation period make possible a complete metabolism experiment, lacking only the measurements of direct heat. Special emphasis has been laid upon the measurement of the metabolism of fasting ruminants when the fast has been begun at different nutritive levels. As a subsidiary problem the influence of environmental temperature upon the metabolism during the first few days of fasting has been studied. In connection with this work, Professor Ritzman has been ably assisted by Miss H. M. Hilton and Mr. A. D. Littlehale, while Mr. E. L. Fox and Mr. H. S. Palmer, of the Nutrition Laboratory staff, have frequently cooperated.

Metabolism of the white rat.—Owing to its relatively short life-cycle and the establishment of its fundamentals by Dr. H. H. Donaldson, it has been customary for workers in nutrition to standardize many food-materials by feeding experiments with the white rat. Thus far little has been published with regard to the actual energy-production of this important laboratory animal. Accordingly, the research at the Department of Nutrition at Teachers College, Columbia University, in cooperation with Professor Grace MacLeod, has been continued this past year, with special emphasis upon the metabolism during growth and during fasting. Miss M. G. Barwis assisted in the experiments.

PUBLICATIONS.

A monograph by Dr. T. M. Carpenter on rectal feeding of alcohol solutions of various strengths, together with certain sugars, is being prepared and is nearly ready for the printer.

- (1) *Grundumsatz und perspiratio insensibilis nach neuen Untersuchungen*. Francis G. Benedict. Schweizerische Medizinische Wochenschrift, vol. 53, Nr. 48, pp. 1101-1104 (1923).

One of a series of lectures given at European laboratories, describing the work of the Carnegie Institution of Washington in general and the Nutrition Laboratory in particular, laying special emphasis upon basal metabolism and the newer experiments on the insensible perspiration. This lecture was given before the Biochemical Society in Berne on April 30, 1923.

- (2) *Undernutrition in steers*. Francis G. Benedict. Proc. Am. Soc. Animal Production (December 1923).

This address, given before the American Society of Animal Production in Chicago in December 1923, discusses in a technical way the researches on undernutrition of steers, carried out at the University of New Hampshire in conjunction with Professor E. G. Ritzman. Emphasis is laid upon the profound physiological alterations induced by the low ration, the effect upon recuperation, and an estimate with regard to the actual draft upon body-material resulting from the prolonged period of undernutrition. The address was illustrated by a series of motion-picture films, showing all the steers at the end of their long period on a submaintenance ration.

- (3) *Alcohol and human efficiency: Experiments with moderate quantities and dilute solutions of ethyl alcohol on human subjects*. Walter R. Miles. Carnegie Inst. Wash. Pub. No. 333, 298 pp. (1924).

A study of typewriting efficiency and simple acts was made on a number of trained subjects with doses of alcohol of 21 to 42 grams in from 14 to 22 per cent solutions. All tests were liberally interspersed with control non-alcohol series. The introduction of alcohol by rectum while the subject slept throughout the night in a respiration chamber was studied in six experiments. A well-trained subject was used in the comparison of the introduction of alcohol (27.5 grams) when given in dilute or stronger doses. A comparison of the alcohol-content of the blood and urine samples was made on a group of 9 men when 27.5 grams of alcohol were taken in 27.5 and 2.75 per cent beverages, respectively. Special attention was given to the more dilute doses. The factors studied were pulse-rate during rest and during work, the oxygen-consumption, the skin-temperature of the face and hands, the amplitude of the patellar reflex, latency and amplitude of the lid reflex, the time for the eye reaction and the word reaction, visual acuity, electrical threshold sensitivity, station, i. e., swaying of the body, the velocity of the eye movements (adductive and abductive), speed of finger movements, coordination for pursuit pendulum and for pursuitmeter, and the transliteration of letters in a code. In typewriting experiments special attention was given to the errors, the number of strokes per second, and to the illegibility. With but few exceptions all the factors studied are concordant in direction, and when comparisons of the same measure may be made, as, for example, eye movements or finger movements, they show fairly good quantitative agreement between the different series. The changes apparently represent a decrease in organic efficiency, inasmuch as they are regularly associated with decreased reflex irritability, slower reaction, less keen, i. e., high sensory thresholds, slower muscular movements, less adequate and accurate muscular control, and less agile mental operations. The factor of accuracy or adequacy of response was more prominently influenced by alcohol than was the factor of speed. Those

coordinations which made a continuous demand on the subject, such as the station or following the pursuitmeter, exhibited a stronger effect than did the discontinuous type of task, such as the reaction time or the pursuit pendulum. In the typewriting investigation it was discovered that with successive series of experiments on the same man, i. e., with the mere repetition of the routine, the alcohol influence in multiplying errors and diminishing the legibility became more pronounced. Food taken just before or with the alcohol lessened the intensity of the effect. Close correlations between the concentration of alcohol in the urine and that in the venous blood and between the depressant symptoms and the concentration of alcohol in the blood or urine were found.

- (4) *Action of dilute alcohol on human subjects.* Walter R. Miles. Proc. Nat. Acad. Sci., vol. 10, pp. 333-336 (1924).

A brief presentation of material published in detail in Publication No. 333 of the Carnegie Institution of Washington.

- (5) *An apparatus for the exact analysis of air in metabolism investigations with respiratory exchange chambers.* Thorne M. Carpenter. Jour. Metabolic Research, vol. 4, pp. 1-25 (1923).

A detailed description is given of a gas-analysis apparatus designed especially for the determination of carbon dioxide and of oxygen in the air of respiratory exchange chambers. The apparatus is constructed on the Haldane principle. The graduation of the burette is designed in such a way that a carbon-dioxide content of 1.700 per cent and an oxygen deficit of 2.000 per cent can be determined. Readings of the volumes in the burette can be made to 0.001 per cent.

A large number of analyses of outdoor air demonstrates that the average carbon-dioxide and oxygen content of samples of gases can be determined to within 0.003 per cent. Detailed directions are given of the technique necessary to obtain accurate and reliable analyses and also for the calibration of the burette and the setting up of the apparatus. The application of the results of an analysis of chamber air to the calculation of the gaseous exchange is shown by means of a theoretical example. The computation of the gaseous exchange is described when the apparatus is used in combination with the respiration apparatus for large animals at the New Hampshire Agricultural Experiment Station.

- (6) *Tables, factors, and formulas for computing respiratory exchange and biological transformations of energy.* Thorne M. Carpenter. Carnegie Inst. Wash. Pub. No. 303A, 126 pp. (1924).

This publication is the second edition of Publication No. 303 (now out of print), in which a compilation is given of tables, factors, and formulas which have been found of service in the calculation of results from data obtained with the various forms of respiration apparatus used with men and animals. The introduction describes the material presented and is followed by a group of tables useful in the reduction to 0° C. dry and 760 mm. mercury pressure of gas volumes, either partially saturated with water-vapor as in a respiratory chamber, or completely saturated as is expired air collected in a gasometer. The various reliable factors and formulas for obtaining the body-surface of man are given; likewise the standards (tables and formulas) for predicting the basal heat-production per 24 hours of all ages and both sexes which were available at the time of publication, these including the standards of Harris and Benedict, Benedict and collaborators, Aub and Du Bois, and Dreyer. A series of tables is also included, giving the factors for converting various units of work, energy, and measures into one another.

- (7) *Methoden zur Bestimmung des Gaswechsels bei Tieren und Menschen*. Francis G. Benedict. Abderhalden's Handbuch der biologischen Arbeitsmethoden, Abt. IV, Teil 10, pp. 415-674 (1924).

This publication is introduced with a discussion of the respiratory exchange as an index of heat-production, the factors affecting metabolism, and the prerequisites for measuring basal metabolism. A complete presentation of the various techniques employed by the Nutrition Laboratory for measuring the respiratory exchange of both animals and humans follows. The simplest form of apparatus, a closed respiration chamber without ventilation, for animals, is first discussed. The universal respiration apparatus, which may be used over a very wide range, i. e., to study the gaseous exchange of a single rabbit or that of a full-grown man working to the limit of human endurance, is described and its attachment to various sizes and forms of respiration chamber considered. A micro-form of the universal respiration apparatus permits the study of rats and mice. Two large respiration chambers are described, one for groups of 25 or less adults, the other for full-grown oxen, each chamber having its unique sampling device. Other types of apparatus described are the portable respiration apparatus and the student form of respiration apparatus for the measurement of the oxygen consumption of humans. In addition, special apparatus employed in muscular-work experiments, i. e., the bicycle ergometer, the treadmill, and the closed respiration chamber, are also described, as well as an apparatus for the exact analysis of atmospheric and chamber air and a mechanico-chemical testing device for respiration apparatus. The description of each apparatus is accompanied by numerous illustrations and an explanation of the method of calculation to be employed in each case. The report concludes with a discussion of the prediction of normal basal metabolism, in which are presented the formulas and tables available at the present time for the prediction of the metabolism of infants, children, and adults of both sexes.

- (8) *Physical factors in predicting the basal metabolism of girls*. Francis G. Benedict. Proc. Am. Philos. Soc., vol. 63, pp. 25-56 (1924).

As a result of the numerous observations on the basal metabolism of children made at the Nutrition Laboratory, various correlations between age, weight, and surface area were established and the conclusion drawn that the closest relationship existed between weight and metabolism, with the age factor playing a considerable rôle. Prediction tables on this basis were presented, but the accuracy of prediction was considerably greater with boys than with girls. For a number of years Pirquet in Vienna has laid considerable emphasis upon the sitting height in its relationship to the food needs of children, and recently Professor Gruber of Munich, analyzing some of the Nutrition Laboratory data, has called special attention to the length factor with adults. A revision of the children experiments, giving due consideration to the length factor, showed that the accuracy in prediction of the basal metabolism of girls was greatly increased by relying upon the length factor with girls from the age of 3 months to 12 years, but from 12 to 20 years the best method of prediction was on the basis of the heat-production per unit of weight referred to age. It is clear that the element of stature has been too long neglected, and with its recognition the order of prediction for girls is now fully as exact as that for boys.

- (9) *The research spirit in modern life*. Francis G. Benedict. Science, vol. 60, pp. 207-214 (1924).

A commencement address delivered at the University of Maine on June 9, 1924.

- (10) *The effect of varying feed levels on the physiological economy of steers.* E. G. Ritzman and F. G. Benedict. New Hampshire Agricultural Experiment Station, Technical Bulletin No. 26, 33 pp. (June 1924).

This bulletin is a digest of a research on undernutrition in steers, discussing the findings with the particular object of pointing out their economic significance under the extremely varying feed-levels, such as are commonly met with on the farm and range, and their influence on the general practice of feeding live stock. The rate of all vital activities appears to vary closely with the changes in level of the feed. The pulse-rate, heat-production, glandular secretion, and physical activity all decreased with reduced rations. This whole picture was completely reversed when fattening rations were given. Health was in no single case impaired by nearly 4 months of undernutrition, and there was no evidence that it limited the regain of flesh and fat lost. It is shown that the rate of regain in weight of steers which have been brought through a whole winter period on 50 per cent submaintenance is exceedingly rapid. Even those steers which received pasture grass only regained their original weight in less than 3 months and, in fact, pasturage proved to be the most economical method of recovering the weight lost by undernutrition. It is also clearly established that rations high in protein are particularly uneconomical in fattening, since the amount of nitrogen that a mature steer can assimilate daily is relatively limited. The tremendous stimulus that a heavy energy intake exerts on physical and vital activities suggests the advisability of limiting physical exercise as a matter of material economy in feeding. No significant differences were observed in thoroughness of digestion of either protein or energy-furnishing materials on different feed-levels or between different individuals, as are so commonly believed to exist.

LABORATORY FOR PLANT PHYSIOLOGY.¹

D. T. MACDOUGAL, DIRECTOR.

Progress in this Department, during the part of the year which has elapsed since the report for 1923 was compiled, may be briefly summarized as follows:

GROWTH AND PERMEABILITY.

Growth in Trees, recorded by the Dendrograph, by D. T. MacDougal.

Studies of growth in trees, chiefly on the basis of records by the dendrograph, have been directed particularly to the Monterey pine (*Pinus radiata*), the redwood (*Sequoia gigantea*), and to the giant cactus (*Carnegiea gigantea*) of Arizona. The total of the continuous records available now amounts to over 110 years. The principal conclusions reached in the earlier studies have been included in Publication No. 350.² Some features of growth in various plants not previously announced in this report are as follows:

The growth of the trunks of the Arizona walnut (*Juglans major*) was measured in the habitat of this species at 8,000 feet in the Santa Catalina Mountains in Arizona and at the Coastal Laboratory. Seasonal activity lasted over 85 days in 1920, 165 days in 1921, and 120 days in 1922 at the Coastal Laboratory. Growth continued for 95 days in a similar tree in the Arizona habitat. Enlargement of the trunk did not begin until the young leaves were expanding. This occurred a month before the maturity of the flowers in the coastal location, and 6 weeks before in the mountain location. The daily variations of the trunk in the habitat of the tree were modified by minute disturbances, probably associated with cloudiness and storms. Reduction of such variations resulted at Carmel from the occurrence of fogs.

The development of a nut of the Arizona walnut was followed at Carmel. Enlargement was modified by a contraction beginning in mid-forenoon and lasting until mid-afternoon, coincident with the period of maximum opening of the stomatal slits on the leaves. Contractions are to be attributed to the withdrawal of water through the stems by the transpiring action of the leaves.

Enlargement of the trunk of the Arizona ash (*Fraxinus arizonica*) begins within 2 or 3 days after the awakening of the staminate flowers and about a week before the leaves start. The seasonal activity of a tree at Tucson, Arizona, lasted 223 days, which is the longest period recorded for any tree, except that of a young Monterey pine at the Coastal Laboratory. The daily equalizing variations were reduced to a minimum in the winter season and were very marked during the period of maximum growth.

The variation in the small trunk of a palo verde (*Parkinsonia microphylla*) tree in the patio of the Desert Laboratory was so small during the season of 1920 that it was not discernible on the dendrograph record.

The bagote (*Parkinsonia aculeata*) was measured in 1921. Enlargement of the trunk occurred before the leaves began to unfold. Activity extended over 193 days, but several pauses, due to deficient water-supply, were included. This and the Arizona ash are the only trees observed by the writer to show activity of the cambium before the leaf-buds awoke. It is to be noted that

¹ Situated at Tucson, Arizona, and Carmel, California.

² D. T. MacDougal and F. Shreve, *Growth in trees and massive organs of plants*, Carnegie Inst. Wash. Publ. No. 350, 1924.

an enlargement accompanying a rain was seen by Dr. Loftfield in *Pinus ponderosa* in 1920 before the buds awoke.¹

The sycamore (*Platanus occidentalis*), measured in the Missouri Botanical Garden in 1920, had a seasonal activity of 125 days, enlargement beginning a month after the activity of the leaves. The daily variation, which is never great, is imperceptible in the time preceding the seasonal awakening, and was much like that of *Parkinsonia*.

The Carolina poplar (*Populus deltoidea*), measured at the Missouri Botanical Garden in 1920, had a seasonal period of but 53 days. Buds awakened at the end of March, but enlargement of the trunk was not observable until May 10, at which time the leaves had not yet reached full expansion.

MacDougal's poplar (*Populus macdougalii*) showed a growing-season of 124 days in a small tree under irrigation at Continental, Arizona, in 1920. A larger tree near the Desert Laboratory had a seasonal period of 199 days in 1921, but many interruptions or pauses were noted. The leaves had attained about three-fourths of their full expansion and the fruits were mature when enlargement began. The daily variations were very slight in the period of inactivity, and not very marked at any time. This fact has not been correlated with conclusions of other authors that the water-content of the trunk may vary widely.

The arroyo willow (*Salix lasiolepis*) at the Coastal Laboratory did not begin growth until May 12 in 1922, at which time the leaves were mature and showed a seasonal period of 119 days with an interregnum of 12 days. The daily variations were of small amplitude at all times.

Growth in Cacti, by D. T. MacDougal.

The cacti are characterized by succulent stems in which is accumulated a large surplus of water, and by a daily program of variations widely different from that of a woody tree.

A dendrographic record of the variations in diameter of the trunk of a sahuaro (*Carnegiea gigantea*), a meter from its base, shows variations, due to varying water-balance, of such wide amplitude and long continuance that it is impossible to fix upon the time when growth, including the formation of new cells and their enlargement, began. It would appear by inference that the apex of these massive stems begins to elongate in April, before a similar enlargement takes place in the main part of the trunk. The daily variations are approximately the reverse of those of the woody trees and of the stems of most herbaceous plants. Swelling begins in mid-forenoon and continues until nearly midnight, when contraction sets in and continues until the next forenoon. This is coincident with the condition of the stomatal slits, which are in a closing condition during the morning hours and narrowest by noon, remaining so until nearly midnight. The amplitude of the variation may amount to as much as 1 part in 200 of the diameter. Variations of all kinds may be much reduced by the action of low temperatures. Increase of soil-moisture by rains has an effect by which general enlargement of the trunk follows within a day after a rain in the warmer season. Such an increase in diameter, amounting to 42 mm., took place in 4 days in July 1923. The general relation of the water-balance of the trunk to precipitation and soil-moisture determined by Mrs. E. S. Spalding is confirmed. The diameter

¹ D. T. MacDougal, *Growth in trees*, Carnegie Inst. Wash. Publ. No. 307, p. 29.

of a trunk in the basal portion was 66 mm. greater on February 9, 1924, than on the same day 2 years earlier.

Growth of the succulent joints of *Opuntia* has several distinctive features. In the younger stage, enlargement is continuous within the tonic range of temperature, an acceleration being seen at midday. At the end of the younger stage the records show that an acceleration of enlargement begins in mid-forenoon and continues until mid-afternoon, when a retardation takes place which is not relaxed in young joints before 6 p. m. and in the older joints not until 10 p. m., when elongation is resumed or accelerated. The stomatal slits are found to be in a narrowed condition between mid-forenoon and mid-afternoon, which may be taken to account for the increased enlargement at this time, in which the higher temperatures would also have a favorable effect. The lessened hydration capacity of the cell-colloids resulting from the acidity, which increases through the night to such an extent that the sap is equivalent to 0.01N malic acid at daybreak, would facilitate water-loss during the night, with its resultant action on the enlargement.

Joints of *Opuntia* grown in the equable climate at Carmel carry out their entire development by a daily behavior similar to that of joints in the younger stage in a desert climate. No contractions ensue. The water-deficit is low at all times, as indicated by the slight swelling of living material when placed in water. The swelling capacity of dried sections is as great or greater than that of similar material matured in the desert location, thus indicating a high proportion of mucilages.

The increase in thickness of the flattened joints of *Opuntia*, which may take place in the second and later seasons of their existence, shows a daily periodicity not parallel in all of its features with those of the increase in length of a young joint. The daily increase in thickness early in the season occurred only in a short period of about 2 hours, ending at midday. With the advance of the season the increase showed only during a later period in the day and later than the acceleration in growth in length.

The auxographic record of the development of a flower-bud shows two maxima—one in which the elongation of the ovular body or fruit is elongating rapidly, and later (when activity in this member is slowing down) the sepals and petals, which are in a compact terminal cone, show an acceleration which holds until they are separated in the opening flower and can not be measured by the auxograph conveniently. Flower-buds at Carmel attained maturity in 41 days at temperatures of 10° to 37° C., and those at the Desert Laboratory opened in 26 days at temperatures which ranged from 10° to 51° C.

Concentration of Cell-contents, Absorption of Water, and Penetration of Electrolytes into Plant-cells, by D. T. MacDougal.

The tissue-fluids or cell-sap of plants show a wide range of variation in concentration. The consequent osmotic potential may be as much as 150 atmospheres in such desert plants as the salt-bush (*Atriplex*), but in ordinary mesophytic plants and deciduous trees the osmotic potential ranges from 8 to 20 atmospheres in the roots and leaves, in the regions in which exchanges with soil-solutions and with the air are effected.

The concentration of the cell-sap determines directly the rate and amount of water which may be taken into the cell and its consequent distention or turgidity. The penetration of ions of salts from the soil should on theoretical

grounds be affected but little by changes in the concentration of the cell-sap. Definite proof as to this matter, however, is not easily to be obtained from living cells, and no results are available. It was therefore arranged to make determinations by the use of the constructed cell, in which the substances of the living cell are arranged in a similar order in a capsule of same size as described in previous reports.

Two series of cells were set up; in one the contents were of 20 per cent sugar solution with an osmotic potential of about 15 atmospheres, and in the other the contents were of 0.6 per cent sugar solution, which would exert an osmotic pull about equal to that of the salt solutions in which the cells were placed. After the cells had been operated for 40 to 48 hours in solutions of chlorides of potassium, sodium, and calcium at 0.01M, the solutions were titrated for chlorine to ascertain whether the cells with the stronger solutions had taken up any more of the chlorine than had entered the cells with the less concentrated contents. It was assumed that each of the above kations would penetrate the colloids of the cell and hence be lost from the immersion solution or medium at the same rate as the chlorine, which would not be exactly correct, but the error introduced would be of no importance in the matter to be tested.

Chlorine determinations were made by direct titration of 25 c. c. of the liquid with silver nitrate at 0.01M. The chlorine was titrated in the original and at the close of the experiment. The results are expressed in cubic centimeters of the silver nitrate necessary to effect the titration. Results from agar-pectin-gelatin lecithin cells, in which 3 parts of gelatin to 5 parts of agar were used in the plasmatic layer, are given below, together with the amounts of water taken in by the cells and measured as outflow:

Contents.	Immersion.	Endos- mose.	AgNO ₃ .		Absorption .
			Original.	Final.	
<i>p. ct.</i>					<i>p. ct.</i>
20	NaCl 0.01M...	10	23.5	18	23
0.6	Do.....	0.0	.....	16.8	28.5
20	{NaCl 0.01 }....	11.6	22.8	16.4	28
	{NaOH .001}				
0.6	Do.....	0.0	22.8	16.5	27.6
20	{NaCl 0.01 }....	8	27.5	16.7	40
	{NaOH .005}				
0.5	Do.....	0.0	27.5	18	35
20	KCl. 0.01	11.2	24.1	18.6	22.8
0.5	Do.....	0.0	24.1	18.2	24.4
20	{KCl. 0.01 }....	9.6	27.2	14.1	48
	{KOH .001}				
0.5	Do.....	0.0	27.2	15.9	41.5
20	{KCl. 0.01 }....	10	30.5	14.9	50
	{KOH .005}				
0.5	Do.....	0.0	30.5	15	50

It was seen that the greater permeability of the cell in any combination was accompanied by an increased adsorption of the salt which produced it.

That as a result of the above the adsorption of sodium was greater than that of potassium from the neutral salt.

That the adsorption of the salt was much greater from alkaline solutions, and the adsorption of potassium much greater than that of sodium in alkaline solutions.

The adsorption of ions by the colloidal cell was but little influenced by the concentration of the cell-contents; the average loss of chlorine from all immersions to cells with contents of 20 per cent sugar solution was 35.3 per cent; to cells with contents of 0.6 per cent sugar solution was 34.5 per cent. The cells of desert plants with highly concentrated sap would therefore have a much greater capacity for taking up water from heavy salt-solutions of the soil, but such concentration of the sap would not cause an acceleration of the passage of ions of the salts into the plant.

*Influence of H-OH Concentration on Hydration and Permeability,
by D. T. MacDougal.*

Results of hydration tests of agar obtained in 1921 show that agar exhibits a greater swelling in dilute solutions of neutral salts than in water. It was also found that this pentosan shows two maxima with respect to the H-OH concentration. One is in the region of HCl 0.0001N about pH 4.2 and the other is in hydroxides at about pH 11.

The hydration swelling of gelatin as representative of the ampholytes is such that increase in concentration of acid or of hydroxide is accompanied by increased hydration and permeability within the biological range of concentrations. It is to be noted, however, that two points of minimum swelling have been found, one at pH 4.7 and at pH 7.7, as determined by Wilson and Kern, and at pH 4.68 and 7.66 as fixed by Higley.

The resultant action, when a composite mass of the two substances is acted upon by acids or alkalies or by neutral salts, will be determined by the proportions of the two present and the relation of the ions in the hydrating liquid to the neutral points, isoelectric zones, or other conditions of the two groups of colloids. The permeability of a protein jelly will be least in the isoelectric zone, and when the gels of the protoplasm are in this condition their permeability is least and the cell will show the highest endosmotic swelling or turgidity. As noted above, increased H or OH concentration in the hydration solution or increased concentration of an electrolyte increases hydration and permeability, while it lessens permeability and increases possible endosmotic action in pentosan gels or mucilages. The solutions which cause a minimum hydration and permeability and the greatest endosmotic swelling may not therefore be the isoelectric points of a vacuolated cell, as suggested by Robbins, but a resultant, or zone in which the low hydration value of a protein is met by a decreasing hydration value of the pentosan. The greatest swelling of a dense non-vacuolar cell would be a similar zone of conjunction of the highest hydration possibilities.

These conceptions are well illustrated by the action of cells constructed of pentosans and gelatin. The maximum turgidity and endosmose coincident with minimum hydration swelling of the two components was in 0.0025N of the acid. A corresponding node was found in the hydroxide at 0.005N. The addition of a salt carried progressive decrease of permeability with the increased H or OH concentration. The addition of lecithin to such cells widens the zones of maximum and minimum action.

No variation was seen in the permeability in 0.001 to 0.005N acid. Neither did the acidification of the salt show much effect, a flattening which is to be seen in the results with living and dead cells. Permeability lessened in hydroxide solution as the concentration was increased to 0.005N, and the maximum lay beyond. The addition of hydroxide to the salt showed a node at NaOH 0.0025N.

Distentions of Living Cells of Opuntia illustrative of the Influence of H-OH and Salts on Hydration and Permeability, by D. T. MacDougal.

That the flattened joints of *Opuntia* show a daily variation of the acidity of the cell-sap near neutrality to a concentration which may be as great as pH 2.5 or even higher (nearly equivalent HCl 0.01) has been worked out with exactness and in great detail by Richards. It was found that the titration values of the acidity might vary as 4 to 1 or even as much as 7 to 1 at certain times.¹

Sets of sections in the acid condition showed the greatest distention or turgidity resulting from the least permeability in HCl 0.0025, equivalent to about pH 2.5, which would be less acid than the cell-sap. Sections in the acid-depleted condition showed the greatest distention or turgidity, and hence the least permeability, in HCl 0.001N about pH 3, which was probably more acid than the cell-sap. Effects were lessened at higher and lower concentration in both cases.

Distention and turgidity and a minimum permeability were found on the OH side of neutrality in NaOH 0.0025N in the morning, or a more acid condition of the cells as well as in the acid-depleted condition in the afternoon. This would be equivalent to about pH 12. All distentions were greater in the acid-depleted condition of the afternoon than in the morning, although the dendrographic records show that the plant has a higher water-content at this hour than in the morning.

Sections taken in the morning and afternoon and hydrated in salt solutions, made acid and alkaline, showed the maximum distention of the highly acid material of the morning in neutral salt solution at a concentration of 0.005M. No variation was found in concentrations of 0.01M–0.0025M in the acid-depleted material of the afternoon.

The maximum distention and turgidity, and hence least permeability, of the living sections in the acid condition as well as in the acid-depleted condition was in NaCl 0.01M+HCl 0.001N. The distention of the highly acid material of the morning in salts made alkaline was greatest in NaCl 0.01M+NaOH 0.001N and NaOH 0.0025, the nodal zone evidently being a broad one. The acid-depleted material showed the greatest distention in NaCl 0.01M+NaOH 0.005N. This lot of material differed from that described above in the reaction to alkali, a variation which might reasonably be attributed to the condition of the material.

Relative Effects of Ions on Permeability of Unstable and Constantly Varying Cell-layers, by D. T. MacDougal.

Permeability phenomena observed in strict and durable, or slowly changing, membranes, such as those of parchment or collodion, offer but distant parallels with the alterations in composition and variations in colloidal condition which are in constant progress in complex series in the layers which ions must

¹ H. M. Richards, *Acidity and gas interchange in Cacti*, Carnegie Inst. Wash. Publ. 209, 1915.

traverse in passing into and out of a plant cell. The wall has a semi-rigid skeleton of cellulose fibers which are capable of but slight changes of volume or of deformation with water-content. The spaces in the external part of this meshwork are occupied by pectins or pectates and the inner part of the meshwork nearest the plasmatic mass contains other liquefiable pentosans, such as mannosans and glucosans, while some lipins or phosphatides occur.

The plasmatic mass is made up of amino-acid chains, pentosans and phosphatides, lipo-proteins, glycolipins, etc. The union of two cells presents an arrangement in which this is doubled. The pectinized layer forming the middle part of the wall and the passage of an ion from one cell to another is attended by all of the adsorptive action of two plasmatic layers, which would never be exactly identical in the two protoplasts. The wall, which is at first largely composed of liquefiable pentosans, progressively includes a larger proportion of the anhydrides as the wall becomes denser and more rigid. Later pectin compounds appear and the maturity of the wall brings it to a condition in which almost any of the salts or organic compounds of the cell as well as fat-soluble substances may pass through the coarser and fixed meshwork. The outer part may undergo secondary changes by which it becomes water-proof in total reversal of the effect of the previous alterations.

The plasmatic mass, at first high in proteinaceous material and in fatty substances, progressively acquires a larger proportion of pentosans or mucilages, with inevitable alterations of reaction to substances included in the vacuole and entering the cell from the medium.

In addition to these changes, which come rapidly in short-lived absorbing cells or root-hairs, this complex membrane is highly unstable as to its composition. The displacements which may occur as a result of the various types of adsorption may result in the loss of bases, such as potassium and sodium, or the leakage of carbohydrates and amino compounds from the liquid or meshwork of the cell, as has been described by True and his colleagues.

Confirmation of the principal conclusions as to the relative action of similar neutral salts of the common bases has been made. Such action runs generally parallel to the ionic mobilities of the bases, which is a straight-line function of the charges they carry. Other factors, the effects of which are still to be measured, are doubtless to be taken into account. The relative action of these bases is modified by the common anions in an order determined by the balance found between the charge on the anion and that on the kation. Thus the common anions $\text{SO} < \text{Cl} < \text{NO}_3$ exert a retarding effect, lessening the action of the kations on colloids in an increasing series as given. This action is in conformity with the hydration effects on agar as measured in 1921 and may be taken to apply within a certain range of effects in which swelling in various degrees results from hydration. Abrupt alterations of effect ensue when the concentrations rise to a point where total neutralization and aggregation of the colloid is brought about.

The most useful explanation which has as yet been offered in this matter is that of Raber, in which these effects are taken to rest upon the relative density of the charges upon the kations and anions acting upon the colloids. This is in accord with the general interpretation by Kahho made two years earlier. The entire matter of interferences, or antagonisms, may yet be found to lie within the operation of such effects coupled with the special reactions of the albuminous material to sodium and of the phosphatides to calcium.

PHOTOSYNTHESIS AND METABOLISM.

Attempts to effect an Asymmetric Carbohydrate Synthesis, by H. A. Spoehr and A. P. Locke.

An extensive series of experiments has been carried out, designed to accomplish the synthesis of optically active carbohydrates by the condensation of formaldehyde under the influence of various chemical and physical agents. It has, however, not been possible to attain such a synthesis with formaldehyde. Further attempts in the same direction have been made with glycolaldehyde. A prerequisite for such a study was more definite knowledge of the conditions governing the condensation of glycolaldehyde to tetroses and hexoses. Asymmetric orientation in this condensation was first attempted through the carboxyl group of dihydroxymaleic acid, whose solutions decompose spontaneously at room temperature into glycolaldehyde and carbonic acid. The condensation of the glycolaldehyde to sugars occurs at a somewhat higher temperature.

Asymmetric condensation of glycolaldehyde to optically active sugars, through the decomposition of active salts of dihydroxymaleic acid to glycolaldehyde and carbonates, was not obtained on account of the precedence of the rate of decomposition over the rate of subsequent condensation. Choice of a condensation catalyst disclosed an unexpected stability in disodium dihydroxymaleate and necessitated the study of the decomposition mechanism. It was concluded from a consideration of reaction rates that the rate of decomposition of dihydroxymaleates is proportional: (1) to the concentration of non-ionized dihydroxymaleate molecules present, (2) to the degree of solvation of these molecules, and (3) to the oxidizing tension of the kations produced by dissociation of the dihydroxymaleate.

Decomposition of a saturated solution of dihydroxymaleic acid at 25°.			Decomposition of a saturated solution of disodium dihydroxymaleate at 25°.		
Time.	Molal concn. of glycolaldehyde + dihydroxymaleic acid.	Increase in molal concn. of glycolaldehyde per min. $\times 10^{-4}$	Time.	Molal concn. of glycolaldehyde + disodium dihydroxymaleate.	Increase in molal concn. of glycolaldehyde per min.
<i>hrs.</i>			<i>hrs.</i>		
0	0	0	0	0	0
0.17	0.28	.....	0.25	0.0174 \pm 2	
0.50	0.35	3.5	1.00	0.0174 \pm 2	0
1.00	0.045	3.3	4.00	0.0174 \pm 2	0
2.00	0.065	3.3	49.5	0.0170 \pm 2	-1.6×10^{-7}
4.00	0.101	3.0			
5.00	0.118	2.8			

It will be observed that the rate of decomposition of the acid is apparently infinitely greater than that of the disodium salt.

Absorption of Carbon Dioxide by Leaf Material, by H. A. Spoehr and J. M. McGee.

The investigations on the absorptive capacity of leaves for carbon dioxide have been continued. It was found necessary to construct apparatus entirely of glass and metal, as accurate results could be obtained only by the

complete avoidance of rubber connections in the absorptive apparatus. The gas analyses were made with a Carpenter apparatus.

The manner of drying the leaves greatly affects the absorptive capacity. The highest values were obtained in material which had been dried at 55° to 60° in a rapid stream of dry air. Higher temperatures are deleterious. Thus, dried and ground leaves of *Helianthus*, to which the same amount of water had been added as originally contained in the leaves, absorbed considerable CO₂ from the air in the dark. The absorption effects are augmented and the accuracy of the determinations increased by using air enriched in CO₂ usually to 1.3 per cent. The dried-leaf material exhibits a relatively high rate of postmortal respiration, and in time becomes saturated with its own CO₂. For this reason it was necessary to free the leaf material of CO₂ by passing a stream of CO₂-free air over it.

Dried and powdered *Helianthus* leaves, to which the same amount of water was added as originally in the leaves and which had been freed of CO₂, absorbed 4.95 mg. CO₂ per gram at 25°, more than ten times the amount dissolved in the water present. Leaf material exhibiting high absorptive capacity also had a high rate of post-mortal respiration and *vice versa*. The post-mortal respiration coefficient (CO₂/O₂) averaged about 1.5.

Extraction of the dried leaves with cold water reduced somewhat the absorptive capacity of the leaf material. Extraction with cold absolute alcohol greatly reduced the absorptive capacity. The material extracted by the cold alcohol absorbed only exceedingly small amounts of CO₂. Similarly, heat tends to destroy the absorptive capacity of the leaf material. Extraction with acetone, thus removing most of the pigments, did not affect the absorptive capacity. Extraction with water saturated with ether at 20° (Chibnall-Schryver method for protein extraction) reduced the absorptive capacity 90 per cent. The residue obtained from evaporating the water-ether extract at reduced pressure and 50° absorbed as much CO₂ as the original leaf material.

These experiments seem to support the theory that the leaf absorbs CO₂ from the atmosphere by a mechanism similar to that by which the blood of mammals serves in freeing the tissues of this gas. According to the experiments, 100 grams of dry-leaf material, when moistened, can absorb at 25° and 1.3 per cent CO₂, 495 mg. CO₂ or 272 c. c. at standard conditions. The dry material constitutes about 15 per cent of the leaf in its original condition, so that 100 grams of fresh-leaf material would on this basis be able to absorb about 41 c. c. of CO₂.

In the leaf, probably the major portion of the CO₂ is absorbed by the proteins on the basis of the carbamino reaction. The effect of this is to increase the concentration of the CO₂ in the cells and to alter the form in which the CO₂ is present. It remains to be determined whether these carbamino compounds can act as photochemical acceptors in the primary photochemical reaction. Experiments on the action of ultra-violet light on the simpler carbamino acids have, however, led to the same negative results as to the formation of the formaldehyde as those with carbonic acid. The primary union of CO₂ with the proteins of the leaf as the first chemical step in photosynthesis may be of considerable importance in determining the cause for the asymmetric nature of the synthesis of the carbohydrates in the chlorophyllous plant.

Oxidation of Carbohydrates with Air, by H. A. Spoehr.

In the report of last year attention was called to the fact that the oxidation of glucose with air in the presence of methylene blue was greatly accelerated by certain iron compounds. It has since been found that sodium ferro-pyrophosphate catalyzes the oxidation of glucose with air without methylene blue. The pyrophosphates of iron are soluble in a solution of sodium pyrophosphate forming salts in which iron is in a complex ion. Sodium ferro-pyrophosphate, $\text{Na}_3\text{Fe}_2(\text{P}_2\text{O}_7)_3$, is a very strong reducing agent, freeing the metal from salts of silver, gold, mercury, and copper.

The mono- and dibasic sodium or potassium phosphates can be added to the sodium ferro-phosphate solution so as to obtain solutions of various hydrogen-ion concentrations. On the addition of glucose to such a solution it turns dark and finally appears black. In an atmosphere of hydrogen the color does not develop, but very small amounts of oxygen produce the color. This reaction is being investigated further.

When air is drawn through a solution containing sodium ferro-pyrophosphate, phosphate mixture, and glucose, carbon dioxide is formed. If the air-stream is rapid the black solution becomes light yellow, but if the air-stream is very slow the color does not change perceptibly. The rate of carbon-dioxide formation at first rises rapidly and then slowly diminishes. An important rôle in the respiratory processes of plants has frequently been ascribed to manganese compounds. The rate at which sodium manganous pyrophosphate, however, catalyzes the oxidation of glucose with air is 0.1 per cent of that obtained with the corresponding iron salt. The rate of oxidation is greatly affected by the amount of sodium phosphate present, as shown by table A.

TABLE A.

Molal concn. of Na_2HPO_4 .	g. CO_2 formed in 216 hours.
0	0.2747
.1	.3808
.166	.4290
.333	.5002

TABLE B.

Molal concn. of KH_2PO_4 .	P.H.	g. CO_2 formed in 216 hours.
0	8.8	0.4690
.1	7.4	.5618
.125	7.2	.6662
.166	7.0	.5756
.25	6.8	.5344

That this is not due to an increase in the hydroxyl-ion concentration is shown in table B, by experiments in which potassium-hydrogen phosphate was added to adjust the hydrogen-ion concentration.

Not only are the reducing sugars oxidized by air in the presence of sodium ferro-pyrophosphate and disodium phosphate, but non-reducing sugars as well.

Equimolecular quantities of the various substances produced, with the same amount of the catalyst, the following amounts of carbon dioxide in 120 hours:

d Glucose..... 0.4874
 Levulose..... .6556
 d Mannose5286
 d Galactose5461

Sucrose..... 0.4462
 Trehalose..... .2024
 Glycerol..... .4752
 Mannitol..... .0362

There is some evidence that glucose in a solution containing disodium phosphate is converted into levulose. Further experiments to establish this mutual transformation and other effects of phosphates on the hexose sugars are in progress.

ECOLOGY AND PHYTOGEOGRAPHY.

On some Features of Foliar Structure of South African Xerophytes, *by W. A. Cannon.*

The dry habitat of southern Africa is one of the most extensive of the subcontinent and has close physical relations with habitats of better rainfall, which differ among themselves widely in other climatic characteristics. Moreover, many of the shrubby species which occur in the arid habitat are closely allied to species of these moister regions, as well as of similar regions in other portions of the world. Such kinship makes a study of structures, especially of the leaf, of especial interest from the standpoint of possible origins. Some conclusions taken from such study may be briefly given.

It was found that often foliar structure, even of pronounced xerophytes, often, or usually, bear the family stamp, and that the structure of the leaf is apparently an easily recognizable variation of such family characteristics. The following partial list of structures summarizes didactically the morphological conditions found in the leaves of xerophytes and of their mesophytic relatives:

XEROPHYTES.

Leaves usually small, or may be wanting; never thin; sometimes succulent.

Trichomes frequently present; may be persistent. Cover trichomes may be associated with marked non-xerophytic type of epidermis. Glandular hair may secrete heavy outer waterproof coating, or may organize ethereal oils.

Outer epidermal wall, usually thick, may be heavily cuticularized and may give rise to an outer cover of wax.

Under arid conditions the polysaccharides may be largely converted into anhydrides or wall material, or in less-arid conditions into pentosans or mucilages. In the former instance the portion of the leaf most exposed is most affected, with the result that usually the outer wall, or not so often the lateral walls, of the epidermis is greatly thickened. In extreme instances this may extend to certain of the more deeply placed tissues. Thus sclerenchyma may be a marked feature. It is usually associated with the conductive tissue.

The leaf structure may be dorsi-ventral or iso-symmetrical. Palisade cells may comprise nearly all of the fundamental tissue, if the latter, or be confined to one side only. If fleshy leaves, the chlorenchyma is cuboid or modified palisades.

Stomata may be superficially or deeply placed. In the latter case this is usually, if not always, the result of the formation of heavy, outer, epidermal walls. The stomatal pit may be constricted at the entrance as well as more deeply by the outer vestibule ridges. A portion of the guard-cell walls may be cuticularized.

MESOPHYTES.

Leaves various; often of large size and relatively thin.

Trichomes often present, at least in young leaves. Cover and glandular hairs occur, the latter of which may secrete various substances, including those which are resinous, and ethereal oils as well.

Outer epidermal wall thin, lightly cuticularized, may be covered lightly with wax of epidermal origin.

The metabolism of the leaf leads to the formation of relatively small amount of cell-wall material and but little material which is mucilaginous.

Structural symmetry usually dorsi-ventral. Chlorenchyma cuboid or palisades.

Stomata superficially placed and provided with outer vestibule ridge. Portion of guard-cells may be cuticularized.

Root-Growth in Cotton and the Minimum Supply of Oxygen, by W. A. Cannon.

It is known that the rate of growth of roots is importantly influenced by two environmental soil factors, among others the oxygen-supply and the temperature. Where the partial pressure of oxygen is adequate, as in well-tilled soil, the rate of root-growth may be modified directly by a change of the temperature of the soil. And, conversely, where the temperature of the soil is suitable and constant, a change in the partial pressure of oxygen, provided it is relatively low, will, within certain limits, directly affect the rate of growth of the root. In the last instance there is an oxygen deficiency, and it happens that the temperature of the soil may in such a case be of great moment in determining not only the rate of growth but possibly the fact of growth.¹

From the foregoing it appears that what constitutes a deficiency of oxygen is a relative matter, depending in part on the temperature of the soil. Oxygen deficiency has two phases, of which one is associated with the least partial pressure at which *normal* growth will take place, and, at the opposite extreme, the other relates to the critical concentration, below which growth stops. The former is of greatest oxygen percentage at the highest temperatures for root-growth and of least oxygen percentage at the lowest temperatures for growth, where, accordingly, it most nearly approaches the critical partial pressure. Therefore, what constitutes both the upper and the lower limits of oxygen deficiency is not constant, but is immediately related to the temperature. In both instances the effect is as if the amount of oxygen present is gradually increased from the higher temperatures of the soil to the lower temperatures. The following considerations suggest that such, indeed, may be the case:

According to Börnstein and Roth,² the solubility of oxygen in water varies inversely with the temperature, as in other gases. Thus, under standard conditions of pressure 100 grams of pure water will absorb 0.004799 gram oxygen at 15° C., and 0.003312 gram at 35° C.—soil-temperatures at which the cotton has been grown. Also, apparently a similar ratio holds in small concentration of the gas for the reason that its density is directly related to the absolute temperature, other conditions being standard, and the amount in solution in water under such conditions is perfectly definite. It would appear, therefore, that in case of oxygen deficiency, and at both upper and

¹ Year Book No. 22, 1923, p. 59.

² *Physicalische-chemische Tabellen*, Berlin, 1912, p. 596.

lower limits of the deficiency, the amount of oxygen in solution in the soil is greater when the temperature is lower than when it is higher, with a corresponding effect on the rate of root-growth. Some of these features can be illustrated by reference to the growth of cotton at different soil-temperatures and in different percentages of oxygen.

The roots of cotton were observed in soil-temperatures between 15° and 35° C., and in concentrations of oxygen between 1 and 8 per cent, with the diluting gas nitrogen.

In 8 per cent oxygen the rate of growth is about normal at 25° C., but falls somewhat rapidly with temperature increase, and at 35° C. it is about 40 per cent normal.

In 2 per cent oxygen the rate of growth is about 80 per cent normal at 20° C., and about 33 per cent normal at 25° C.

Below 1 per cent oxygen, and possibly in 1 per cent, growth of the roots of the cotton does not take place at the higher soil-temperatures, and probably not at 15° C.

In a concentration of oxygen represented by about 1.2 per cent, a slow growth-rate occurs at 15° C., but growth does not go on at 30° C. or 35° C. It is apparent, therefore, that the critical concentrations of oxygen lie between about 1 and about 1.5 per cent for soil-temperatures between 15° and 35° C.

Curves showing root-growth in cotton in a deficiency of oxygen, but at different temperatures, plotted against a curve of oxygen solubility for the same temperatures, are strikingly alike, whether the oxygen deficiency is great or little. They indicate, further, that the march of the critical percentage, as well as that of the upper limits of oxygen deficiency, in the temperature range used, is in small amounts, of little entire range, and, thus, quite comparable to the known variation in oxygen solubility for the same temperatures.

Root-growth in Cotton under Normal Conditions of Temperature and Oxygen-Supply, by W. A. Cannon.

It has long been known that in young plants the growth of the main root exhibits at first a gradually accelerating rate of growth to a maximum, followed by a decrease in the rate, and it has been more recently established that also in later stages the growth-rate can be characterized as being a succession of more rapid, followed by less rapid, rates, all of which can be represented graphically by S-curves. The slowing of the growth-rate is related to the formation of rootlets.¹ The first of such regular fluctuations of growth has been called the "grand period" of growth, which was at first, and subsequently, determined by measuring the increase in length of the main root, which was not adequate for the determination of the relation of laterals to such type of growth. The latter was first learned through weighing the main and the secondary roots. In the case of cotton, here to be reported, the time-relation of the two characteristics of root-growth referred to have been determined by direct observation and the quantitative relation by a comparison of the relative volumes of main root and of secondary roots.

A characteristic feature in the early development of the cotton (*Gossypium barbadense* var. *pima*) is the pronounced development of the main root before laterals are formed. In the case of cotton the main root at this time may be

¹ J. H. Priestly and A. F. C. H. Evershed, *Growth studies: I. Quantitative study of the growth of roots*, Ann. Bot., 36, 239, 1922.

16 cm., or less, in length. Up to this time the daily growth may vary between about 20 to 80 mm. for temperatures 21.5° and 30° C. The following will illustrate the daily growth of a typical main root at a constant soil-temperature of 21.5° C. during the "grand period": 15, 20.5, 22.5, 22, 28, 32, 31.5, 32, 21.5, 22, and 22 mm. Up to the fifth day no laterals were to be seen, but on the fifth day, when the growth was 28 mm., the rudiments of several laterals appeared as translucent spots on the main root, and on the sixth day, marked by a growth of 32 mm. of the main root, about 16 laterals had emerged. During the two succeeding days about 75 rootlets made their appearance, and their growth in length, which was from 2 to about 5 mm. daily, was accompanied by a rapid decline in the growth-rate of the main root, as indicated in the measurements cited above.

On the last day of the observation the total volume of the rootlets and of the main root was determined. At this time it was found that the volume of the laterals was about 525 cu. mm. and the total length about 550 mm. The daily increase in length of the rootlets was about 10 times that of the main root, and at the end of the observations the daily increase in volume was approximately 3 times that of the main root. When plotted as a curve it was found that the main root exhibited the expected S-shape, but that the line representing the growth of the root-system as a whole was a consistently ascending one.

Deserts of Northwestern Sonora, by Forrest Shreve.

In November 1923 an expedition was made by automobile from the Desert Laboratory to the shores of the Gulf of California at a point halfway between Guaymas and the mouth of the Colorado River. The course lay southwest from Tucson to Sasabe, thence south to Altar, west to Pitiquito, and south and west to the shores of the Gulf at Libertad, thence south to Kino Point. The entrance into Mexico was made among low hills at an elevation of 3,500 feet. After crossing an extensive grassy plain, falling gradually south and east, the flood-plain of the Rio Seco was followed to Altar. The vegetation of this region is essentially identical with that of the flood-plains near Tucson, and the new species that appear in it are not so striking as the new ecological habits exhibited by some of the familiar plants. Two conspicuous cacti are first seen about 20 miles north of Altar—*Lophocereus schottii* and *Lemaireocereus thurberi*, the former occurring on alluvial and outwash soils, the latter on hills.

Throughout northern Sonora the vegetation of the flood-plains and alluvial areas is more nearly like that of southern Arizona than is the vegetation of the hills. On the coarse gravelly mesas, the characteristic plants are chiefly species of wide distribution in the Sonoran desert, such as *Covillea tridentata*, *Parkinsonia microphylla*, *Olneya tesota*, *Carnegiea gigantea*, *Acacia paucispina*, *Opuntia fulgida*, and *Fouquieria splendens*. The distribution of *Carnegiea* overlaps with that of the still more massive *Pachycereus pringlei*, both of which occur on coarse outwash slopes and on hills, being always more abundant on south slopes.

The valleys lying east of the Sierra Picu, the most westerly range of mountains, have a deep loam soil and a rich cover of vegetation. *Covillea* is infrequent here, and large trees of *Parkinsonia*, *Olneya*, and *Prosopis* are intermingled with *Carnegiea*, *Pachycereus*, large colonies of *Lophocereus*,

occasional groups of *Lemaireocereus*, and a large *Yucca*, which often reaches a height of 25 feet. Smaller cacti and numerous species of shrubs, together with mats of the gray-grass *Hilaria*, all combine to make a highly diversified plant community.

In the Sierra Picu and the lower ranges of hills which lie between it and the Magdalena River the general groundwork of the vegetation is composed of species which extend to the northern edge of the Sonoran desert, but a large number of shrubs, cacti, vines, and herbaceous plants are first seen here. One of the most striking and abundant of these is *Elaphrium microphyllum*, the copal tree, of the family Burseraceæ. The platyopuntias, or prickly pears, become very much less abundant in this region than they are at Tucson, both as to the number of species and individuals.

The last one of the low passes in the Sierra Picu is 20 miles from the Gulf coast and its elevation is approximately 1,750 feet. The very gradual descent to sea-level is made over a detrital slope on which the vegetation is at first very heavy, then rather open, and finally very scanty and low. The vegetation of the heavily covered portion of the slope presents many features which distinguish it from similar situations to the east and north. The giant *Pachycereus pringlei* here reaches its maximum size, and *Lemaireocereus schottii*, *Opuntia fulgida*, and *O. gosseliniana* are also abundant. The principal distinctive features of the area, however, are the great number of small trees and the abundance and variety of shrubs and shrub-like perennials. The shrubby vegetation not only includes the compact type, branching freely from the ground, but numerous individuals of malvaceous and solanaceous shrubs, with a single erect stem and the form of a small tree. Some of these are not woody and their presence is a strong indication that frosts are very light in this locality.

The Bay of Libertad is a slight concavity in the coast-line, stretching from Point Lobos on the north to Kino Point on the south, a distance of about 12 miles. At Kino Point a low range of granitic hills abuts directly on the coast. In sandy soil at the base of the outwash slopes, which stretch north from these hills, was found the heaviest stand of *Pachycereus* noted on the entire trip, accompanied by large and numerous examples of *Elaphrium microphyllum*.

On approaching Kino Point the eye is arrested by what appears to be a forest of small trees denuded of their branches and leaves, extending along the base of the hills. This proves to be the cirio, *Idria columnaris*, of the family Fouquieriaceæ, previously known only on the peninsula of Lower California. The trunk of this singular tree is from 12 to 18 inches thick at the base, but tapers very rapidly to a slender top and rarely exceeds 20 feet in height. The trunk itself occasionally forks into two or three branches, all of which continue to grow in a vertical position. From base to top the trunk is beset with short, slender, lateral branches, growing in a horizontal position and bearing thorns and seasonal leaves after the manner of *Fouquieria*. The large racemose inflorescences are borne only at the upper end of the trunk or its branches. The trunk is smooth, of a pale salmon color, and the cortex is so soft that it can be cut with great ease.

The heaviest stands of *Idria* were along the base of the granitic hills. It is infrequent on the upper slopes, and nowhere grows very far away from rock in place. Unlike most plants at the northernmost limit of their occurrence, *Idria* is more abundant on north slopes than on south slopes. It was found

inland from Point Kino as far as the hills extend, and southward as far as the second ridge of hills below the point which marked the southern limit of our expedition.

Throughout these hills *Idria* is the most conspicuous plant, *Pachycereus*, *Lophocereus*, and *Lemaireocereus* are all infrequent, although they may be found in the valleys and on alluvial slopes. *Carnegiea* is confined to the hills, but nowhere reaches its customary size. *Parkinsonia* is very uncommon, and *Covillea* is confined to coarse detrital slopes at the bases of the hills. On the slopes there are few large individuals of any plants.

The vicinity of Libertad and the hills of Kino Point were of particular interest as examples of a pronounced desert, running right down to the shores of a large body of water. While the temperature conditions here are extremely favorable, there is every evidence that the precipitation is much less along the coast than it is 10 miles and more inland. In November 1923 the writer installed non-evaporating volumetric rain-gages at Libertad and at the pass in the Sierra Picu, 18 miles from Libertad. At the latter locality a Six's maximum-minimum thermometer was also installed. These instruments were read in March 1924 by Mr. Gilbert Sykes. The precipitation at Libertad was 1.0 cm. and at Picu Pass 4.8 cm., while for the same period at Tucson it was 11.2 cm. The minimum temperature at Picu Pass was 34° F., and for the same period at Tucson 27.5° F. These figures indicate the extreme aridity of the coastal belt and show that the precipitation of the hills nearest the coast is considerably higher. The minimum temperature reading shows that there are at least occasional winters without frost. At Libertad and Kino Point freezing temperatures doubtless occur only at rare intervals and for periods of very brief duration.

Influence of Slope Exposure on Soil Temperature, by Forrest Shreve.

The work previously done on this subject has been under natural conditions, which present differences in the depth and character of the soil and in the nature of the surface and the plant covering. In order to secure a precise measure of the influence of slope exposure under ideal conditions, a small hill was thrown up on the flood plain of the Santa Cruz River, near the Desert Laboratory. The hill is composed of fine alluvial clay throughout, has a height of 10 feet, with a ridge running east and west, and slopes with an inclination of 30° from the horizontal. The hill was made in the spring of 1923 and was left for one year to become settled. In March 1924 three soil thermographs were installed at a depth of 3 inches, one on the north slope, one on the south slope, and one on level ground of the same character near the hill.

The earliest records were influenced by the fact that the moisture-content of the level ground was higher than that of the hill. After the course of the arid fore-summer had reduced the three soils to the same low moisture-content, the differences in the readings were influenced solely by the slope exposure of the surfaces.

A comparison of the average weekly maximum during April and May shows the south slope to be from 9° to 13° hotter than the north slope. The difference as previously measured under natural conditions at the same altitude has invariably been less than this, and the least in the hottest months. At 7,000 feet elevation an average difference of 13° was found on the Santa

Catalina Mountains in the summer of 1922. The average weekly maxima for the south slope and the level ground were nearly the same during April, the south slope being 1.4° warmer in the week of greatest difference. Beginning with the second week of May, the maximum for the level ground began to be greater than for the south slope. This is to be explained by the fact that on the approach of the summer solstice the sun's rays fall more directly on level ground than on a slope of 30° southern inclination.

The well-known phenomenon of "inversion of zones," by virtue of which plants of low altitudinal range may be found on south-facing slopes overlooking sublevel plains occupied by plants of higher range, is due to differences in soil-temperature and other conditions determined by it. The close similarity of soil-temperature conditions on south slopes and level ground in the early summer, when moisture conditions are critical, would indicate that the differences underlying the "inversion" are operative in fall and winter, when temperature conditions are critical and the low position of the sun may be expected to give a greater contrast in the soil temperature of slope and level.

Evaporation in Redwood Habitats, by Forrest Shreve.

Evaporation readings were secured in the summer of 1924 at Rocky Creek, 14 miles south of Carmel, with a view to determining the evaporation conditions in different types of redwood habitats and in adjacent vegetations. Rocky Creek is one of the most southerly localities for the redwood, and the evaporation figures here given are for the period in which the annual course of moisture conditions is most trying for this tree, following the rainless months of spring and preceding the mid-summer period of fog. The stations extend from a distance of 1 mile inland to about 3 miles inland from the coast.

The character of the stations and average rates of evaporation per day from the porous-cup atmometer are as follows: (1) Open, north-facing slope 1 mile inland, characteristic of conditions for wind-swept mottes of small trees. Rate, 17.3 c. c. (2) Open south-facing slope with chaparral of *Salvia*, *Artemesia*, and *Lupinus*, not invaded by redwood. Located 1.5 miles inland. Rate, 21.5 c. c. (3) Sheltered north-facing slope with young, vigorous stand of redwood. Located 1.5 miles inland. Rate, 9.3 c. c. (4) Open area in lateral valley leading north, with redwoods on adjacent slopes. Located 1.5 miles inland. Rate, 16.3 c. c. (5) In heavy stand of large redwoods 3 miles inland on lower slopes of lateral valley. Rate, 7.2 c. c. (6) In an open area above the redwoods in the same valley with station 5. Rate, 13.1 c. c.

The figures given indicate approximately the annual maximum rates of evaporation, and therefore the limiting values for this condition as one of the principal determinants in the local distribution of the redwood. The readings taken in the shade of large trees (station 5) and of small trees (station 3) are respectively 7.2 and 9.3 c. c., and indicate the low rates of water-loss to which the lower foliage of trees in close stands and that of suckers and seedlings is subjected. The readings taken in open areas near stands of redwood (stations 4 and 6) indicate the rates of evaporation (16.3 c. c. and 13.1 c. c.) to which the exposed and uppermost foliage of large trees is subjected, and under which reproduction is not taking place. The readings at station 1 (17.3 c. c.) indicate the conditions under which reproduction is difficult and trees exist only in stunted form in compact groups with "wind-trimmed"

crowns. The adjacent chaparral-covered slopes at station 2 show a rate of 21.5 c. c., to which the crowns of some of the uppermost trees may be subjected, but a rate at which reproduction and invasion are impossible.

In the summer of 1923, readings of evaporation were taken from May to September on the summit of the ridge north of Rocky Creek. The highest rate secured was 22.9 c. c. per day. This is only 1.4 c. c. greater than the reading secured at station 2, and shows that, so far as evaporation is concerned, the conditions are just as unfavorable on the lower, south-facing slopes, just above the uppermost existing trees, as they are on the ridges.

Vegetation of a Desert Valley, by Forrest Shreve.

During the spring of 1924, work was continued in the Avra Valley, west of Tucson, in extension of the previous studies of this area of indeterminate drainage. Intensive work done two years ago on a small portion of this valley, which presents the maximum differentiation of soil conditions, gave some useful data on the mechanical composition and soluble salt-content that appear to present optimum conditions for the few but very dissimilar communities of plants by which the valley is covered. In the present year a more general survey has been made of the soil conditions over the entire valley, and the vegetation has been mapped on a coarse scale for the region of indeterminate drainage, with special reference to the open, park-like stands of mesquite (*Prosopis velutina*), the pure or nearly pure stands of creosote bush (*Covillea tridentata*), and the areas which are either bare or poorly covered with salt bushes (*Atriplex* spp.) and species of *Lycium*. The bare areas frequently contain numerous dead trees of mesquite, sometimes 30 to 50 years in age, and the character of the surface and the local drainageways indicates that a local cycle of flooding and deposition has so greatly reduced the aeration of the soil as to be fatal to trees that had found favorable conditions in that spot for many years. A series of bench-marks, placed 4 years ago across one of the bare areas, proves that there has been an additional deposition of from 2 to 4 cm. in the center of the area, while the edges have already begun to be washed away from 0.5 to 2 cm. In one case the development of a new drainageway, very faintly forecasted in 1920, has reduced the level 7 cm. at a bench-mark 2 meters from it. The re-establishment of the mesquite in this area has begun only slightly along the marginal streamways which are developing, and there is no evidence that the conditions of aeration of the soil during the rainy seasons are now any better than when the regression originally took place.

The most elevated portions of the floor of Avra Valley, which have gone the longest time without overflow and deposition, are principally occupied by pure stands of creosote bush. Although this plant is capable of growing in soils with an even higher soluble salt-content than is found in the bare areas, it appears to be able to withstand the occasional reductions in oxygen-content of the soil-atmosphere. The mesquite occurs in soils exhibiting a relatively wide variation in soluble salt-content. Its customary habitat is on alluvial soils of the finest texture, but these must present good conditions of soil-aeration. On coarse soils the mesquite is infrequent and small, but this is due to the fact that the moisture-content of the coarse soils is at all seasons lower than that of the alluvial soils. So far as soil-conditions are concerned, there appears to be a margin between the optimum conditions

for mesquite and those for creosote bush; in the Avra Valley, however, there are no localities where the two plants grow in approximately equal admixture, the stands of creosote bush in particular being 95 per cent pure throughout the valley. It remains to be discovered what other conditions may be concerned in determining the vegetation in habitats where the known soil-conditions appear to be equally favorable to mesquite and to creosote bush. The former is a plant of great reproductive vigor, while the latter establishes new individuals very rarely. Although there is no means of determining the precise age of individuals of the creosote bush, its habit of growth indicates that large plants may be at least 100 years old. There is some evidence in the facts given that some of the communities of these two plants may be relicts, in a limited sense, persisting in a locality which formerly presented their optimum conditions and in which secular changes have now so modified the conditions as to bring them nearer the limiting values. Physiographic changes taking place in opposed directions might bring about a close similarity of soil-conditions in spots occupied by different communities of plants, and under desert conditions these communities might persist in their original purity for many years.

DEPARTMENT OF TERRESTRIAL MAGNETISM.¹

LOUIS A. BAUER, DIRECTOR.

JOHN A. FLEMING, ASSISTANT DIRECTOR.

GENERAL SUMMARY.

INTRODUCTION.

The present annual report is the twenty-first since the establishment of the Department in 1904. It will be found to contain evidence that during the period of its activity the Department of Terrestrial Magnetism has been enabled to accumulate and coordinate a large amount of data of increasing interest to those concerned with the solution of the problems pertaining to the magnetism and electricity of the Earth and to the electrical properties of its atmosphere.

Like other lines of investigation in cosmical and terrestrial physics, which might readily be cited, our accumulated data and interpretative studies will receive additional value by continued intensive observation and theoretical investigation of the ever-varying phenomena. It would seem to be of paramount importance with the rapid strides being made at present that students of cosmical and of terrestrial physics keep their theories in a "colloidal" condition.

Since we can not bring the body—the Earth—which is the chief object of our investigation, into the laboratory and experiment upon it, as we are accustomed to do with an ordinary magnet, we must depend for steady increases in our knowledge as to causes for magnetization, or for electrification, of the Earth upon careful and intelligent observance of the phenomena disclosed when Nature herself performs some striking experiment upon our Earth-magnet, or upon our electrically-charged Earth. Such experiments Nature performs during the day, during the seasons, during the year, from year to year, during total solar eclipses, and at times spasmodically, as for example, during periods of magnetic or electric storms, which are accompanied frequently by displays of polar lights and interruptions in telegraphic transmission.

The problems of interest to us concerning the electrification of the atmosphere and its rapid variations, and concerning the electrical currents ever flowing in the Earth's crust, are likewise of interest to the student of radio-telegraphy and to the student of telephonic and telegraphic transmission.

Our observations and investigations thus not only have their bearings upon the advancement of knowledge of the structure and constitution of matter, but may also yield results of practical benefit to mankind.

The various sections of this report will show how we are making provision to meet both the demands of theoretical and applied science by conducting simultaneously researches pertaining to the observational work in the field and at the observatories, and to the laboratory and theoretical work at Washington.

With the aid of the additional magnetic data and the accurate reductions to a common epoch, as described in various sections of this report, it is hoped that it will soon become possible to make another analysis of the Earth's magnetic field to supersede the preliminary one for 1922, the results of which were described in the report for the year 1923 (pp. 229, 230).

¹ Address: Thirty-Sixth Street and Broad Branch Road, Washington, D. C.

It should be noted that the present report applies to the period November 1, 1923, to June 30, 1924, and not, as in previous years, to a complete year, November to October.

INVESTIGATIONAL WORK IN WASHINGTON.

The general investigational work conducted during the period, November 1, 1923, to June 30, 1924, in the Department's laboratory in Washington was as follows:

TERRESTRIAL MAGNETISM AND ELECTRICITY.

Relations between solar activity, terrestrial magnetism, atmospheric electricity and earth-currents.—The Director's investigations on the relations between solar activity, terrestrial magnetism, atmospheric electricity, and earth-currents have disclosed interesting relationships between the diurnal and annual variations and earth-currents, terrestrial magnetism, and atmospheric electricity. The largest and most consistent correlation coefficients for the Ebro Observatory at Tortosa, Spain, were found between the variations of earth-currents and the rate of variation, or time-gradients, of the atmospheric potential-gradient. It is hoped that we may soon have the requisite data from our own observatories for the further investigation of this interesting result. The investigation of the relations between solar activity and atmospheric electricity was continued with the aid of data supplied especially for the purpose by the Kew, Eskdalemuir, Ebro, and Potsdam observatories, and the concluding manuscript on these relations was nearly completed in June. The Director was assisted in the necessary reductions and computations chiefly by Messrs. W. J. Peters, C. R. Duvall, C. C. Ennis, and Miss Emma L. Tibbetts. For an abstract of the results of the first publication on this investigation, see pages 169 and 173. Investigation was begun on the question as to whether atmospheric-electric phenomena do not show somewhat different results on days greatly disturbed magnetically from those found on the so-called international magnetically-calm days.

Measure of the Earth's magnetic activity.—Various methods of investigation for obtaining in a simple manner measures of the Earth's magnetic activity sufficiently adequate for use in general investigations pertaining to the correlations between solar activity, terrestrial magnetism, and terrestrial electricity were made. Considerable attention was given to some recently suggested methods of rating the activity of the Earth's magnetic field at observatories, especially to that proposed by Dr. Suminosuke Ono, of Japan. Chief assistance in this work was given by Mr. W. J. Peters.

Magnetic data and charts for polar regions.—Lack of absolute values and data for magnetic secular changes over the polar regions introduces many uncertainties into the construction of polar charts of the magnetic elements. These charts are all necessary for progress in the complete analysis of the Earth's magnetic field, but the magnetic declination chart, which is the most difficult to construct for lack of data, is also of utilitarian value in future navigation of the air. Considerable study and some progress have been made by Mr. W. J. Peters in the magnetic declination chart of the north polar regions, where the data obtained from the recent expeditions cooperating with the Department have been of great value.

Investigation of daily and seasonal changes in the potential gradient of the atmosphere.—While at the Watheroo Magnetic Observatory, Dr. G. R. Wait has been studying the relation between changes in the potential gradient

as observed on the *Carnegie*, daily and seasonal, and he has given attention to hypothetical considerations concerned with electromotive forces supposedly induced by the rotation of the Earth's magnetic system in interplanetary space. His investigations, though not yet completed, show a remarkable coincidence of the *Carnegie's* curves of atmospheric potential-gradient with the curves of these hypothetical changes drawn for the times of equinoxes and solstices.

Publication and lecture work.—For publications in scientific journals and papers before scientific societies, see abstracts on pages 167 to 186.

The Director gave a number of lectures and addresses during the year, among which were the following: "On the origin of the Earth's magnetic and electric fields," before the Brooklyn Institute of Arts and Sciences, November 24, 1923; "The Earth and Sun as Great Magnets," before the Eastern Association of Physics Teachers, at Boston, December 8, 1923 (see abstract, p. 172); "The Magnetic Earth and the Electric Atmosphere," before the Royal Canadian Institute, at Toronto, January 5, 1924 (see abstract, p. 170); "The Earth's Magnetism and Electricity and the Work of the Non-Magnetic Ship *Carnegie*," before the West Lynn (Mass.) Branch of the American Institute of Electrical Engineers, January 16, 1924; "The Magnetism of the Earth and the Electricity of the Atmosphere," being the annual Sigma Xi lecture at Rutgers College and the State University of New Jersey, March 17, 1924. He also prepared and presented, on April 27, 1924, to the Division of Foreign Relations of the National Research Council, a report on "The Activities of the International Geodetic and Geophysical Union and the American Geophysical Union, 1923-24." On February 23, he presented to the Pick and Hammer Club at Washington a brief summary of possible bearings of researches in terrestrial magnetism upon problems relating to the interior constitution of the Earth.

Research associates.—Dr. A. E. Kennelly, of the Massachusetts Institute of Technology and of the Harvard Engineering School, and Dr. S. J. M. Allen, professor of experimental physics at the University of Cincinnati, were connected during the year with the Department as research associates of the Institution. Stimulating and helpful conferences were held at Washington with them by the Director and members of staff on various salient topics relating to atmospheric electricity, earth-currents, and vertical electric currents, and to the interpretation of results of investigations already completed. Dr. Allen was at the laboratory in Washington during January 24 to February 13, familiarizing himself with details of the observational and investigational work in terrestrial electricity; he sailed on February 16 for England, where he spent some time in visiting magnetic and electric observatories in Great Britain and in conferring with eminent British investigators. Conferences with Dr. Kennelly were held in Washington on April 27, May 1, and May 2.

Dr. Allen addressed the Philosophical Society of Washington on February 9 on "Passage of X-rays through matter and the atomic structure of commercial materials."

Miscellaneous.—In connection with the investigations above noted, Messrs. Peters and Duvall have developed and arranged special forms for the Fourier analysis of periodic, magnetic, or electric variations, with the least possible amount of calculation and tabulating.

Besides the conferences above referred to with research associates, numerous conferences were held with eminent physicists on various problems pertaining to terrestrial magnetism and atmospheric electricity. The Director and the Assistant Director attended on December 15 a conference of directors of the departments of the Institution interested in the physical sciences, called by President Merriam to consider possible lines of investigation suitable for co-operation between the departments. Conferences on the various lines of activity of the Department of members of the investigating staff have been held since January 1, 1924, in the Director's conference room, on the average, about twice a month.

EXPERIMENTAL WORK IN MAGNETISM.

Magnetization by rotation.—Dr. Barnett's experimental work on magnetization by rotation in the Experiment Building was completed December 31, 1923. Beginning with January 1, 1924, his status was changed to that of a research associate of the Institution and he was assigned to continue his experimental work on magnetism in general at the California Institute of Technology in Pasadena.

Mathematical and laboratory investigations.—Following the recommendation of the special conference of January 20, 1922 (see pp. 268 to 270 of the Department's report for 1922) "that provision be made, as soon as conditions permitted, to add to the Department's staff a well-trained mathematical physicist to assist the Director in his theoretical studies," arrangements were completed for the appointment from July 1, 1924, of Dr. Gregory Breit, assistant professor of physics of the University of Minnesota, 1923-24. Among the investigations under consideration are (a) existence of vertical electric currents, (b) the Earth's precise action on a magnet, (c) electromagnetic nature of the Earth's interior by experiments on electrical constants of circuits made by connecting long cables in series, and (d) effect of pressure on the critical temperature of magnetization.

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY.¹

Atmospheric-electric apparatus and instructions for observatories.—Two recording bifilar quartz-fiber electrometers supplied by Messrs. Günther and Tegetmeyer of Germany were tested before forwarding to the Watheroo and Huanayo observatories to be installed pending the completion of the standardized observatory type of potential-gradient recorder of the Department. Chief assistance in these tests, made in the deck observatory and on the grounds of the Department at Washington, was given by Messrs. H. F. Johnston and O. W. Torreson.

The experimental observatory on the deck of the Laboratory at Washington, pending the establishment of a permanent station for terrestrial electricity in the United States, was continued in operation, daily records of the potential gradient and negative conductivity of the atmosphere being obtained; the operations of several steam shovels in the neighborhood of the Laboratory have decreased during the year the number of usable records.

Further progress was made on the detailed design of the standardized potential-gradient apparatus for atmospheric-electric observations at observatories. Ionium collectors were prepared especially for the Apia Observa-

¹ From the report of chief of the section, S. J. Mauchly.

tory. Mr. O. H. Gish attended to the laboratory work necessary in making up quartz-fiber suspensions for string electrometers and other instruments. A special device was designed to facilitate increased accuracy in observations for determining the capacity of atmospheric-electric instruments.

Memoranda relating to the control of ionium collectors employed for potential-gradient registration at the Department's observatories and directions for making the required observations were prepared. Careful study was given to all accumulated conductivity records obtained by means of the Department's standard recording conductivity apparatus at the Watheroo Magnetic Observatory to determine its efficiency under actual observatory conditions and to serve as a basis for further improvements of apparatus; detailed memoranda based on the results were prepared dealing with the operation and improvement of the apparatus.

Reduction of atmospheric-electric observations.—Continuing the final compilation of constants begun last year, observations and reductions were made for the constants and corrections of the following atmospheric-electric instruments used on board the *Carnegie* during cruises IV, V, and VI: ionic content, conductivity, penetrating radiation, and radioactive content. Certain theoretical considerations that had arisen in the preliminary reductions of the *Carnegie's* work made necessary extended experimental observation to determine the best methods and safeguards for eliminating errors of capacity determinations and of other fundamental quantities, not only for the work done at sea but also for field and observatory procedure and methods. In preparing tabulations for the manuscript of the volume on final ocean magnetic and electric results obtained during 1915 to 1921, there will be incorporated results of recomputations of the electric observations for cruise IV (1915–16) provisionally published in volume III of *Researches of the Department of Terrestrial Magnetism*, on the basis of the new and improved constants.

Among other reductions carried out during the year were the following: (a) Negative conductivity as recorded in the deck observatory at Washington; (b) revision of potential-gradient summaries and tabulations for several months in the latter part of 1923 from Apia Observatory; (c) general control for electric classification of days and methods of reduction; (d) final reductions of meteorological observations on the *Carnegie* necessary for consideration in relation to the atmospheric-electric results; (e) preliminary study of the atmospheric potential-gradient records at the Watheroo Magnetic Observatory, this showing good agreement with the universal-time law indicated by Dr. Mauchly's discussion of data obtained at other land stations and on board the *Carnegie* (see last year's report, pp. 262–263).

Polar-light investigations.—Studies bearing on this subject were continued, including preparation of a report for presentation at the annual meeting of the American Geophysical Union in May 1924 (see abstract, p. 181).

Special and cooperative work.—(a) The central office of the Weather Bureau at Manila was supplied, upon request, with detailed instructions and list of required apparatus for the determination of potential gradient of the atmosphere at land stations. (b) Cooperation with the Department of Agriculture in the boll-weevil investigation, including (1) loan of apparatus for use in connection with the studies of the electrical charges carried by certain insecticides when delivered into the air either by machines operated on the

ground or by aircraft, (2) training of observer, and (3), after the Bureau of Standards assumed responsibility for the instrumental equipment and electrical problems arising, cooperation was continued in various conferences with members of staff at the Bureau who were assigned to the work and in suggesting a high potential attachment to the bifilar electrometer that would permit of measurements of the high potentials experienced in the course of experiments. (c) Preparation of atmospheric-electric data obtained at the deck observatory at Washington and the Apia Observatory upon request of Mr. C. N. Anderson, of the American Telephone and Telegraph Company, for use in connection with investigations concerning correlations with radio transmission (see p. 152). (d) Supplying of data in response to a large number of inquiries received for atmospheric-electric results, particularly of potential gradient, for the investigation and study of possible correlations with human health conditions. Among these were communications from the statistician of the National Tuberculosis Association, Mr. R. R. Bowker, of New York City, and Dr. R. H. Milwee, of Dallas, Texas, with the latter particularly in connection with his desire to establish properly equipped stations near Dallas for obtaining continuous records.

*Progress in earth-current work.*¹—The earth-current work continued in charge of Mr. O. H. Gish. The Watheroo earth-current records were carefully examined to determine the quality or appropriateness of the experimental earth-current measuring system, methods, and instruments, as installed by the Department. Some of these results were set forth in memoranda. Designs for a modified form of recorder for use later at our Huancayo Magnetic Observatory in Peru were made and the new instrument was tested and adjusted with some assistance from Observer Coleman. Only a small amount of time was left for the investigation of electrodes for use in earth-current measurements.

The earth-current potential-differences, as recorded almost continuously since the latter part of October 1923 at our Watheroo Magnetic Observatory in Western Australia, are for the present being reduced at the office and studied with a special view to ascertain their reliability and to effect improvements in the methods of measurement. The results indicate that, although some features doubtless can be improved, yet on the whole the method being tried out by our observers is very satisfactory. For further data regarding this work, see abstract on page 180. Chief assistance in this work was given by Mr. C. R. Duvall, who gave considerable attention to ways and means of facilitating the reduction of records.

In January 1923, in response to an invitation from General J. J. Carty, vice-president in charge of the Department of Development and Research of the American Telephone and Telegraph Company, a visit was made by Mr. Gish to the New York Office of that company, where its records of earth-current storm observations were examined. Several series of the great amount of usable data there available were selected for more detailed study. Earth-current storm data observed during the same storms at the Ebro Observatory and during other storms at Kaafjord, Norway, and at Watheroo, Western Australia, were put in suitable form and compared with these. This investigation seems to show that data obtained in this way on telegraph lines will be of considerable value in the study of earth-current storms, furnishing

¹ From subreport by O. H. Gish, associate physicist.

some evidence that probably could not be obtained in any other way. An account of this investigation is abstracted on page 180. Mr. C. R. Duvall assisted in these earth-current storm studies.

Methods and instruments for earth-resistivity measurements were investigated. Prior to designing apparatus suited to our special needs, earth-resistivity measurements with a McCullom "earth-current meter" were made on the Department's site at Washington. The results of these measurements have some interest, and are summarized on page 179. Apparatus designed to fill the needs indicated by this preliminary work was designed, constructed, and tested.

Miscellaneous.—Attention was given to the preparation of charts and other matter relating particularly to atmospheric-electric and earth-current work for the annual exhibit held in December 1923 at the Administration Building of the Institution. In connection with necessary experimental work in development of earth-current apparatus for observatory use some time was devoted by Mr. Gish to planning a special exhibit illustrating earth-current phenomena to be included with the annual exhibit in December 1924. An electrograph with the necessary insulating supports and appurtenances and visual reading arrangements was designed and prepared for the permanent exhibit installed in the building of the National Academy of Sciences and of the National Research Council (see p. 166).

Publications.—Progress was made on the preparation of manuscript dealing with the atmospheric-electric work on the *Carnegie* and with the compilations of atmospheric-electric data from records obtained at the Department's experimental observatory at Washington. Two papers were read by Dr. Mauchly at the Cincinnati meeting of the American Physical Society, abstracts of which are given on pages 182 and 183; he also gave a talk on "Atmospheric electricity" which was broadcast from the radio station of the Radio Corporation of America at Washington as one of a series of semi-popular talks on scientific subjects under the direction of the Smithsonian Institution; this paper, which is briefly summarized on page 183, is to be published in the magazine Q S T of the American Radio Relay League.

Mr. O. H. Gish gave an illustrated talk on "Natural electric currents in the Earth's crust" before the Washington Section of the American Association of Mechanical Engineers, and also prepared papers on "The system for recording earth-currents at the Watheroo Magnetic Observatory" and on "Results of preliminary earth-current measurements at the Carnegie Institution's magnetic observatory near Watheroo, Western Australia;" these are abstracted on pages 178 and 180.

OBSERVATIONAL AND ADMINISTRATIVE WORK.

Land magnetic survey.—The period covered by this report has been one of great activity in magnetic surveys all over the globe; this activity has been stimulated by the extensive and carefully coordinated field operations of the Department and by its cooperation with other organizations in magnetically unexplored countries. During the year information was received of plans for magnetic resurveys and extension of magnetic surveys from the heads of governmental organizations in Argentina, Brazil, Mexico, New Zealand, South Australia, Soviet Russia, Siberia, and Turkestan. A considerable amount of magnetic-survey work was accomplished, through the cooperation

of the Department with expeditions in the loaning of instruments, and by the Canadian Government through its Dominion Observatory and its Meteorological Service at a large number of stations in high northern latitudes and within the Arctic Circle—regions where additional magnetic data are greatly needed for the analysis of the Earth's magnetic field (see p. 146).

Observatory work.—Continuous registrations of the magnetic declination, horizontal intensity, and vertical intensity, electrical conductivity, and potential gradient of the atmosphere are being made at both the Watheroo and Huancayo observatories. The earth-current program at the Watheroo Observatory (Western Australia) is on a satisfactory basis, and it is hoped that the earth-current installations may be made at the Huancayo Observatory (Peru) some time in 1925.

Following the indications of investigations on magnetic disturbances, arrangements to effect better time control have been made at the observatories through the installation of suitable radio equipment for receiving time-signals. The Department has cooperated with the United States Coast and Geodetic Survey in many matters pertaining to field and observatory work, and particularly the control of magnetic standards along the lines recommended at the Rome meeting of the International Section of Terrestrial Magnetism and Electricity. Through the courtesy of the Coast and Geodetic Survey, instruction in observatory methods and procedure was given several recently appointed observers of the Department.

Cooperative work.—The Department of Development and Research of the American Telephone and Telegraph Company was supplied, upon request of Mr. C. N. Anderson, with magnetic and atmospheric-electric data for use in connection with the investigations and researches regarding correlations of terrestrial magnetism and electricity with conditions of radio transmission. In reporting upon the work done, Mr. Anderson feels satisfied that there is a definite connection between terrestrial magnetism and electricity and radio transmission, since the magnetic storms of the latter part of February and March 1923 and of October 1923 and of February 1924 left unmistakable effects upon the radio-transmission curves; in general, this effect is an increase in the daylight field strength and a very marked decrease in the night-time values. In less severe cases the night-time transmission is marked by excessive fluctuations. The correlation between earth-current, potential-gradient, and solar disturbances seems more obscure than that between the latter and variations of the Earth's magnetic field.

In anticipation of cooperation later in a program of atmospheric-electric work, particulars regarding installation of an electric generating plant were supplied for use at the Tucson Observatory (Arizona) of the United States Coast and Geodetic Survey. Blue-prints showing construction details for magnetic observatories and for atmospheric-electric and earth-current observatories were supplied to the Director of the United States Coast and Geodetic Survey for use in connection with the transfer of the Vieques Observatory to the main island of Porto Rico.

Numerous requests were received during the year for magnetic information and for data regarding geographic positions of the Department's stations. Such information was supplied to the General Staff of the British Army, American Museum of Natural History, the Shansi Governmental University and Industrial College of North China, and the Government of Nicaragua.

OCEAN WORK.¹

Requirements of future ocean work.—Considerable time was given to a study of the best means to meet the needs of future magnetic and electric work at sea. While more information upon secular-variation changes in the Earth's magnetism is required for navigation, yet future ocean magnetic work is far more necessary for the advancement of theoretical studies. Similarly, a discussion of the ocean electric results shows the urgent need for more widely distributed electric data for the study of the Earth's electric field. A point of first importance in considering the continuation of the ocean survey by the *Carnegie* is that of the resulting enhanced theoretical value of the work already done.

The fields of theoretical investigation which future magnetic and electric ocean work should cover include:

1. *Terrestrial Magnetism:*

- (a) Determination of secular variations of the Earth's magnetic field, particularly their accelerations which accumulated data indicate may not be safely extrapolated over periods as long as five years; accurate data are necessary for a number of epochs to advance the investigation of causes producing and laws governing these changes. (b) The study of regions of local disturbance, and particularly of those indicated by the previous work of the *Carnegie* over "deep-sea" areas, including accompanying determinations of gravity and of ocean depths. (c) Determination of additional distribution data in some large areas not already covered.

2. *Terrestrial Electricity:*

- (a) Additional determinations of changes in the values of the atmospheric-electric elements with geographic position; such distribution data are needed in the further investigations on the origin and maintenance of the Earth's electric charge and of the relations to the Earth's magnetic condition. (b) Further widely distributed determinations of the diurnal variation in atmospheric electricity particularly to confirm the discovery that such variations in the potential gradient progress with universal time, a deduction first indicated from results obtained on the *Carnegie*; sea conditions for such work are superior to those on land where variable meteorological conditions and topography mask the true characteristics of the phenomena. (c) Determinations and investigations of oceanic electric currents.

A study was made to determine whether the theoretical requirements (1) and (2) above stated could be realized by means other than continuation of the ocean work, as, for example, through land work only. The maximum control that could be so effected for the ocean areas by observations at stations on the coasts and on islands would not be sufficient, since the local disturbances so generally prevalent on islands would introduce uncertainties in the relations between normal and actual values as well as in the secular-variation changes, and since the ocean regions would be large for which the necessary data for continued theoretical investigations would be lacking. Thus, assuming that an appropriate distribution of the secular-variation stations need not be greater on the average than one in every 600,000 square miles, large areas which would lack secular-variation control would approximate

¹ From the report of the chief of section, J. P. Ault.

3,400 by 800 miles in the north Pacific, 3,600 by 1,500 miles in the east central Pacific, 3,600 by 1,800 miles in the south Pacific, 600 by 600 miles in the north Atlantic, 2,400 by 800 miles in the middle north Atlantic, 1,900 by 900 miles in the west south Atlantic, 1,500 by 700 miles in the east Indian, 3,600 by 750 miles in the central Indian, and 2,400 by 900 miles in the southeast Indian to the south of Australia.

As regards atmospheric electricity, discontinuance of the use of the *Carnegie* would restrict distribution observations of atmospheric-electric elements to relatively few stations and at relatively great expense, since, to eliminate for short series of observations the topographic and meteorological conditions at land stations, only selected points in wide bays or estuaries where it would be possible to observe on floats could be used. Atmospheric-electric observations could be obtained on board ordinary vessels, and doubtless some of the steamship companies could be interested to the extent of permitting the installation of the necessary equipment at reasonable cost, but it is not feasible to obtain on such vessels the necessary calibration observations, nor, despite the most earnest cooperation, is it possible to control the deck space and eliminate the effects of smoke and exhaust gases. Furthermore, it would be necessary to repeat such work and control such conditions on many vessels in order to accomplish the necessary distribution of observations over the oceans. Despite the considerable expense that would be incurred, the accumulated data would be subject to many uncertainties. It is therefore to be hoped that in the near future means may be provided to continue the observations and studies of the magnetic and electric conditions over the oceans.

Vessel maintenance.—The *Carnegie* has continued out of commission in Washington at the wharf of the Washington and Colonial Beach Steamboat Company; the necessary precautions and safeguards were taken to maintain her in as good condition as possible under the circumstances.

Final reduction of ocean atmospheric-electric observations.—In order that all observations made on the *Carnegie* during the period 1915 to 1921 may be included in one volume, submission for publication of manuscript on the ocean magnetic results was delayed pending the final revision of the extensive ocean atmospheric-electric and associated meteorological observations. This work was begun early in 1924 by Captain Ault under the general direction of Dr. S. J. Mauchly, chief of the Section of Terrestrial Electricity. Because of certain theoretical considerations (see p. 149) modifications were found necessary in the constants used for atmospheric-electric data already reported upon for Cruise IV (1915–16) in volume III of the Researches of the Department; these were recomputed for republication in a forthcoming volume of ocean magnetic and electric results.

Methods for upper-air observations for the magnetic elements and their variations.—As opportunity offered, the problem of determining effects of change in the magnetic elements with change in altitude was considered and some time was given to the study of the conditions under which upper-air investigations must be made, of the possibility of obtaining absolute measures of requisite accuracy, and of possible information that might be derived from a study of relative differences in the variations as determined simultaneously through continuous registrations at stations, differing greatly in elevation but at relatively small distances apart. The establishment of one or two

temporary magnetic observatories at sea-level, for example, one near Lima and another in the Amazon country, in connection with the Huancayo Magnetic Observatory in Peru, seems a promising method of gathering data for the problem. (In this connection see p. 176.)

Special cooperative work and publications.—The reductions of the magnetic observations obtained by the Department in California and Guatemala during the total solar eclipse of September 10, 1923, were compiled and revised and a report was prepared by Captain Ault for publication. Mr. H. F. Johnston compiled and prepared for publication the results of the corresponding atmospheric-electric observations made at Point Loma, California. Abstracts of these two papers are on pages 168 and 181. In connection with these observations, some of the extensive magnetic data obtained during the eclipse, in accordance with the special program of the Department, by cooperating organizations and observers was examined and reported upon by Captain Ault.

Advantage was taken in connection with the preparation of matter for the annual exhibit of Institution activities to prepare five large-scale ocean charts suitable for reproduction in the volume on ocean results and showing each station at which observations have been obtained by the *Carnegie* and *Galilee* during 1905 to 1921.

The chief of the ocean section (Capt. J. P. Ault) was designated by President Merriam as delegate on behalf of the Carnegie Institution of Washington to attend during July and August 1924 the meetings of the Conference on Oceanography convened by the Honorable the Secretary of the Navy to consider matters pertaining to a proposed United States Navy expedition for research in oceanography.

The following papers and lectures were given by the chief of the ocean section: "Effects of the solar eclipse of 1923 on the Earth's magnetic field," presented before the Philosophical Society of Washington; "Surveying the oceans on the non-magnetic yacht *Carnegie*," a radio talk broadcast May 21, 1924, from the Washington station of the Radio Corporation of America. Abstracts of these are given on pages 168 and 169. Captain Ault also delivered his lecture "Sailing the seven seas in the interest of science" on three different occasions.

LAND MAGNETIC SURVEY.¹

In planning the field work for the year attention was centered chiefly on obtaining secular-variation data at stations where magnetic observations had been made previously by the Department and other organizations. While the need for extensive distribution data has been met largely by the past field work of the Department and by the field operations stimulated in many countries, opportunity was taken during the Department's recent expeditions to secure some additional distribution data in a few regions not before covered. With the completion of work now under way, secular-variation data for the present epoch will be available for South America, the West Indies, and those portions of North America not included in the work of the Canadian and United States Governments. The same is true for all of Australia and for the accessible island groups of the Pacific. Plans are well advanced for extending the secular-variation program to Africa and the other countries of the eastern hemisphere.

¹ From report of the chief of section, H. W. Fisk.

The general plan of making field observations for diurnal variation in all three magnetic elements at selected stations designated as Class I stations (see p. 237 of the annual report for 1923), inaugurated in 1922, has been continued with encouraging success. A comprehensive plan for a system of Class I stations at which it is hoped such observations may be repeated at intervals of a few years has been drawn up.

Field operations.—Observer D. G. Coleman, who had been in Australasia and the southern Pacific for nearly three years, concluded his field work at Saigon, French Indo-China, early in January 1924. He returned to Washington, arriving March 1, and later was assigned to observatory work. The work of Observer W. A. Love in the northern part of South America and in Central America, begun in June 1922, was brought to a close in November 1923. At the conclusion of this work Mr. Love returned to Washington and resigned his position, which was filled by the appointment of Mr. John Lindsay. Observer R. H. Goddard remained with the MacMillan North Greenland Expedition, and Observer J. T. Howard spent the entire period of this report along the Amazon River and its tributaries in Brazil and Peru. The reoccupation of stations in Mexico, which has been necessarily delayed, was undertaken by an expedition leaving Washington early in June 1924, in charge of Observer J. W. Green, who was assisted at the start, for purpose of training in field work, by Mr. Lindsay.

A brief synopsis of the land magnetic survey work done since that described in the annual report of 1923 and through June 30, 1924, follows:

Asia.—In connection with his work in the Dutch East Indies, Observer D. G. Coleman reoccupied the C. I. W. station at Singapore, Straits Settlements, during November 27 to 29, 1923, and at Phantiet and Saigon, French Indo-China, during December 28, 1923, to January 4, 1924. The last two points have a peculiar interest in that, up to the present time, they are the only stations at which the horizontal intensity has been found to exceed 0.400 c. g. s. unit. This magnetic element is increasing generally in this region, as it was approximately 0.398 c. g. s. unit in 1912 at these same stations. Somewhat larger values were then found farther west at Pnompenh and in vicinity of Bangkok, Siam, though no values at that time were as great as the present values at Saigon and Phantiet. With the work in French Indo-China, Mr. Coleman had completed a period of almost three years in the field and returned to Washington, where he arrived March 1, 1924.

Africa.—By an arrangement with the Liberian Boundary Survey, instruments were supplied and training in methods of observation was given that data might be obtained in a region not otherwise easily reached (see annual report for 1923, p. 240). The work is under the direction of L. C. Daves, chief engineer of the survey, who is expected to return from the two-years' field work about the end of December 1924.

Australasia.—Only the synopsis of Observer D. G. Coleman's work in Queensland and Northern Territory, Australia, July to October 1923, made up from his cabled report of progress, was included in the last annual report, as the detailed account of his work was not available in time for publication. He left Sydney, New South Wales, in the latter part of June and went to Mackay and Townsville, Queensland. The conditions of travel in that state were much less favorable in 1923 than they were during the former visit of the Department's observers in 1912 to 1913. Because of economic conditions prevailing, many of the towns had either disappeared or contained but a remnant of the former populations, train service had been greatly curtailed, boat service along the coast was much less frequent, and opportunities for

securing comfortable accommodations were greatly diminished. A very good distribution of repeat stations for secular variation over this part of Queensland was obtained by going first west to the railway terminus at Cloncurry. A horse coach was employed at that point for the trip north to Normanton at the head of the Gulf of Carpentaria, a distance of nearly 300 miles, and thence the weekly railway service was used to Croydon, about 80 miles east. The Royal Mail autotruck furnished transportation overland eastward to the railhead at Forsayth, from which weekly train service was secured again for Cairns on the coast. Here, by the fortunate arrival of a coastal steamer, passage was secured to Cooktown in good time to catch the monthly mail steamer for Thursday Island, at the extreme northern point of the York Peninsula. On this trip, 11 widely distributed repeat stations were occupied, at three of which, Townsville, Cloncurry, and Thursday Island, the extended Class I program for diurnal variations was carried out; at two, auxiliary stations were established; and at most of the others the entire program was repeated, sometimes twice, on successive days. On Mr. Coleman's arrival at Darwin, in Northern Territory, September 15, it was found impracticable because of travel conditions to reoccupy stations other than those easily reached by the railway and the station at Point Charles Lighthouse. Five stations in this region were reoccupied, including Darwin, which was made a Class I station. On October 16 he sailed for Batavia, Java.

Cooperation has been continued with Government Astronomer, G. F. Dodwell of South Australia, who has taken steps to continue and enlarge the interest in magnetic work in that region, largely as the result of the stimulus given by the Department's activities. Assistant Astronomer A. L. Kennedy reoccupied the station of 1911 at Burra in October and November 1923 as a Class II station, and had in hand plans for other expeditions on which magnetic work was to be done.

Absolute observations, as well as continuous registrations of the three magnetic elements, were made throughout the year at the Watheroo Magnetic Observatory in Western Australia (see p. 159).

North America.—After concluding his work in Guatemala, Observer W. A. Love returned along the west coast to Panama City, where the former station was reoccupied October 10 to 11, 1923. From there he went to David, Panama, and later to San José, Costa Rica, reoccupying the stations of 1907 at both places. As this concluded his work in Central America, and because a serious accident made it advisable to return the magnetometer to the shop for repairs before using it in contemplated work in Mexico, Mr. Love returned to Washington, where he arrived on November 26, 1923.

On June 8, 1924, Observers J. W. Green and J. Lindsay left Washington for work in Mexico. They entered that country from Eagle Pass, Texas, and after observations at Sabinas and Monterrey, C. I. W. stations of 1907, they proceeded to Mexico City, where comparisons were obtained by Mr. Green with the standard instruments of the observatory at Teoloyucan, while Mr. Lindsay made observations at Puebla and reoccupied the station of 1907 at Oaxaca. After a little further work together, Mr. Green will proceed alone to stations in western and northern Mexico, while Mr. Lindsay will take up work in southeastern Mexico and later a series of reoccupations for secular variation in South America.

Islands, Pacific Ocean.—Observer D. G. Coleman concluded his work in northern Australia at Darwin and arrived at Batavia, Java, on October 24, 1923. After a comparison of his instruments with those of the Royal Meteorological Observatory at Weltevreden, he made use of the opportunity to reoccupy during November and December some stations of the East India Survey of 1907 in the Malay Archipelago. These stations were Makasser in

southern Celebes, Bandjermasin in southern Borneo, and four stations in British North Borneo.

South America.—Observer J. T. Howard, after reoccupying repeat stations at Obidos and Santarem, on the Amazon River in Brazil, secured permission from those in authority to ascend the Paru River. He returned to Para to prepare his outfit and left again on September 26 for Almeirim, where the expedition was started. Ascent of the river was very slow and difficult because of the stage of the water and the numerous rapids, more than 50 of which were passed. The river was followed to a point in about $0^{\circ} 16'$ north latitude, when the Indian guides refused to go farther because of superstitious fears of dangers ahead. Rather than retrace the course, the canoes were abandoned and the trail overland to the Jary River was found and followed for four days to a village on a tributary of that stream. Descending was comparatively easy, as there was but one portage, where a rubber company maintained burros by which the labor usually required in such cases was greatly lightened. As this region has not been traversed before by magnetic survey parties, all the stations except that at Almeirim, at the point of departure from the Amazon, were new stations. Nine stations were occupied on the ascent and four on the descent. The party disbanded at Para at the end of December. A few days were spent at Para in recovering from malaria, after which Mr. Howard went to Manaus, where that station was reoccupied as a Class I station on January 24 to 26, 1924. The steamer service on the larger Amazon tributaries is quite infrequent and uncertain, due mainly to the condition of the rubber business, and only by the loss of much time can work be undertaken along such streams without independent transportation. Early in February two stations, Santa Isabel and Barcellos, on the Rio Negro, were reoccupied, and in March a trip was made up the Madeira, on which the stations at Guayaramerin and Porto Velho were reoccupied. Returning to Manaus, the ascent of the Amazon toward Iquitos was begun April 10. It was found impracticable to attempt many stations en route, because of the few suitable places and the short stay of the steamer at each. The monthly service maintained by the steamer made the necessary waiting interval undesirably long for any plan of breaking passage at intermediate points. Notwithstanding these difficulties, observations were made at three of the ports at which the steamer called. After making observations at Iquitos, Peru, a special invitation was received by Mr. Howard from President Leguia of Peru to accompany a surveying expedition to the headwaters of the Marañon, which was to have started about May 1; unfortunately, departure of this expedition had to be postponed, and it was necessary later to decline the invitation with regret on account of the enforced delay. Leaving Iquitos June 1, Mr. Howard began the ascent of the Ucayali River to Puerto Bermudez, where he arrived about June 21 and proceeded by way of Tarma for Huancayo. A cablegram announced his arrival there on July 10. Along the route from Iquitos to Huancayo four C. I. W. stations of 1912 were reoccupied.

Absolute observations and continuous photographic registrations of the three magnetic elements were continued throughout the year at the Huancayo Magnetic Observatory in Peru (see p. 161).

Arctic regions.—Observer R. H. Goddard, who was assigned to the MacMillan North Greenland Expedition which left Wiscasset, Maine, on June 9, 1923, spent the entire period covered by this report with that expedition at the winter quarters of the *Bowdoin* at Refuge Harbor, on the west coast of Greenland (lat. $78^{\circ} 31' N.$, long. $72^{\circ} 27' W.$ of Greenwich). Besides the absolute magnetic observations made in connection with the operation of the temporary observatory there, it was expected that some stations in places accessible by sledge journeys would be established by Mr. Goddard and Dr.

MacMillan during the winter and spring; the detailed report of the work accomplished, however, will not be available until the return of the expedition, probably in September 1924.

The vessel *Maud* of Captain Amundsen's Arctic Expedition (see p. 238 of last year's report) continued throughout the season in the Arctic ice north of eastern Siberia, the latest radio information giving the position of the vessel on February 11, 1924, as latitude $75^{\circ} 13'$ north and longitude $156^{\circ} 45'$ east of Greenwich, this being in the neighborhood of the New Siberia Islands. The plans of Dr. H. U. Sverdrup, in charge of the scientific work of the expedition, included regular magnetic observations on the ice during the progress of the drift. A radiogram received January 10 stated that about 140 observations of all the magnetic elements had been made at stations on the ice during the first winter (1922-23).

Survey control at Washington.—Instrumental outfits returned from or assigned to field parties during the year were compared with the standards of the Department at the Standardizing Magnetic Observatory, and their constants were determined as necessary. This work was done under the direction of Mr. J. W. Green, who also instructed Messrs. R. T. Booth and John Lindsay, newly appointed observers, in magnetic-survey methods and control.

Reduction of field observations.—All land magnetic work for the three years 1921 to 1923 was reduced and made ready for final tabulation preparatory to publication in a volume of the Researches of the Department, the larger part of the manuscript text for which was completed by Mr. Fisk. Messrs. Fisk and Duvall have developed a differential method to facilitate computations required to determine distribution-coefficients for magnetometers (see p. 174). Mr. Fleming has compiled and investigated further the corrections on the provisional International Magnetic Standards of the Department for magnetometers and inductors (see p. 176). Time-changes of the moments of inertia of the magnets and their suspension stirrups as used for observations of oscillation are shown to be in general the cause of observed differences from time to time in the corrections on intensity standard; these changes of inertia-moment, as shown by the compilation of data, vary almost linearly with time while the instruments are in field use, so that corrections on standard may be determined with a precision well within all practical requirements for survey work. The corrections for magnetometers in declination and for inductors in inclination are indicated as constant within the limit of observational error.

OBSERVATORY WORK.¹

The progress at the magnetic and electric observatories for the period of this report may be briefly summarized as follows:

Watheroo Magnetic Observatory, Western Australia.—Dr. G. R. Wait continued in charge of the observatory through April 1924, when he transferred it to Mr. H. F. Johnston, who arrived at Watheroo on April 15. The observers-in-charge were ably assisted during the period of this report by Observers J. Shearer, who left the observatory on February 1 to take up post-graduate work at the Melbourne University, O. W. Torreson, who reported at the observatory to take Mr. Shearer's place on December 29, 1923, and J. E. I. Cairns.

The magnetograph was in continuous operation and all necessary routine work connected with the control of the magnetograms was carried out regularly. On January 3 the kerosene lamp used for illumination of the magneto-

¹ From the reports of the Assistant Director and of the observers-in-charge.

graph was replaced by an electric lamp; this change greatly improved ventilation conditions in the magnetograph room.

The atmospheric-electric apparatus for recording positive and negative conductivity was kept, as far as possible, in continuous operation during the year. The records for negative conductivity are practically complete, but owing to the unforeseen mechanical wear in the positive unit of the apparatus, records for positive conductivity were not complete during November to May 1924. Recording was stopped during April 26 to May 9, 1924, for readjustment of the entire apparatus and for mechanical improvements on the positive side; complete records have been obtained since May 9. The observatory type of apparatus for continuously recording the potential gradient was installed at the end of December and continuous records initiated on January 1, 1924. All necessary routine work connected with the control of the electrograms for conductivity and potential gradient was carried out regularly. Observations for reduction-factor, by which observed potentials are reduced to volts per meter, were made practically once each month. Complete calibrations of each conductivity unit for the determination of scale-values were made occasionally, but will be made weekly hereafter, and calibrations of the electrostatic voltmeter were made as found necessary. Some observations in visibility and on the number of dust particles in the air were made, using for the latter an Aitkin's dust-counter loaned by the Commonwealth Meteorological Bureau. The few data thus far obtained indicate a direct relationship with the atmospheric-electric elements.

The earth-current recorder was in continuous operation, registrations of the difference of potential between electrodes 1 mile apart on both subterranean and aerial lines, and of electrodes 2 miles apart on aerial lines being obtained. The necessary routine work for the operation of the recorder for calibration and for time control were maintained. Various tests were carried out from time to time to insure the efficient operation of the system.

The program of meteorological observations was continued and, as in the past, resulting data were supplied to the office and to the Australian Commonwealth Weather Bureau at Melbourne. A Jordan sunshine recorder has been in continuous operation throughout the year and a hygrograph since January 1.

Except for the earth-current records, the preliminary computations required in the interpretation of the magnetograms and electrograms, together with the tabulations of hourly scalings, were completed at the observatory before being forwarded to the office for final reduction. The observatory reductions and tabulations are now current. Statements of the magnetic character of days and reports and descriptions of magnetic storms and earthquake records as recorded were prepared regularly. The mean values of the weekly determinations of the magnetic elements during 1923 are: declination, $4^{\circ} 20' 9''$ west; horizontal intensity, 0.24779 c. g. s. unit; inclination, $64^{\circ} 02' 8''$ south.

Following the practice adopted by the Department, the time of changing of all the daily records was altered, beginning May 8, so as to have them begin at about 8 o'clock, one hundred and twentieth meridian east standard time, the standard adopted at the observatory, thus making each record practically cover a Greenwich mean day. Time control at the observatory was effected through the receipt of daily time-signals by radio.

The buildings were kept in repair. The top of the atmospheric-electric and earth-current observatory was covered with copper screen and the sides of the building with copper screen-cloth during December 1923. A veranda around the quarters is in the course of construction. The agricultural experiments undertaken to determine the most suitable type of fertilizer for use on the sandy soil around the observatory, in cooperation with the State Department of Agriculture of Western Australia, were continued. To overcome the diffi-

culty of transportation between the observatory and Watheroo referred to in last year's report, a Citroen car with a Kegresse endless driving-belt attachment was purchased and delivered at the observatory in June.

The continued cordial interest of the Federal Government is evidenced by the action of the Minister of Customs in authorizing free entry of the Citroen car and of other equipment consigned to the Observatory. The continued cordial attitude of government officials and of leading men of science in Australia deserves special mention.

Huancayo Magnetic Observatory, Peru.—The magnetograph was kept in continuous operation throughout the year. Some loss of record was occasioned during February through trouble with the oil-burning lamp; at the end of that month the lamp was replaced by electric illumination and since then practically no record of magnetic variation has been lost.

The electric conductivity apparatus was recording continuously between late October to early May, with occasional losses of records from instrumental causes. Early in May it was necessary to stop recording in order to make necessary mechanical improvements. The new parts from Washington were received and fitted early in June, some readjustments were made, and the apparatus has functioned since then with much more satisfactory results. The potential-gradient apparatus for the atmospheric-electric observations was operated continuously since its installation early in February with but little loss of trace; insulation troubles happily were remarkably slight. Pressure of other work and unfavorable weather conditions prevented the full number of standardizations being made in the earlier part of the year, but in future the regular semimonthly comparisons will be made.

The usual daily meteorological observations have been maintained and reduced. The recording barograph and thermograph in the atmospheric-electric observatory and the recording hygrometer in the thermometer shelter have operated continuously. Abstracts of meteorological data from January 1922 were supplied to the Cerro-de-Pasco Copper Corporation at Oroya.

Intercomparisons between the field equipment of Observer J. W. Green and the observatory standards were made between September 2 and 6. Observations of magnetic declination and atmospheric potential-gradient were made at intervals of one minute during the total solar eclipse of September 10.

Because of the pressure of construction and installation work, the computational work and tabulation of records from recording instruments was, until early in 1924, somewhat meager. Some progress was made in the reduction of the electrograms. In April the magnetograms and control data for March 1922 to December 1923 were sent to the office for reduction, together with the absolute magnetic observations for the two years 1922 and 1923, these having been computed at the observatory. The observatory reductions and tabulations are now current. Progress was made in scaling the barograms (corrected to standard barometer) and the sunshine records. Statements of the magnetic character of days and reports and descriptions of magnetic storms and earthquake disturbances as recorded were prepared regularly. The mean values of the weekly determinations of the magnetic elements during 1923 are: declination, $8^{\circ} 04'.6$ east; horizontal intensity, 0.29786 c. g. s. unit; inclination, $0^{\circ} 45'.6$ north.

The practice of changing all daily records so as to have such records start at practically the zero hour of Greenwich mean time was continued. The radio receiving apparatus worked well and control of corrections on standard for timepieces was effected through receipt of daily time-signals from Balboa.

The buildings were kept in repair and various improvements were made. The latter included covering of the Delco-plant building with Malthoid roofing, completion of another rain-water cistern of 4,000 gallons capacity,

the beginning of construction of garage and driveway in anticipation of the early completion of the road to Huancayo, and the building of an additional bedroom at the west end of the attic in the quarters. An intercommunicating telephone system for the quarters, office, atmospheric-electric observatory, and potential-gradient field station was installed in February. Various improvements were made on the observatory site, including the planting of 40 eucalyptus trees along the driveway from the quarters to the entrance gate, and the laying of concrete paths between the electric-plant building, quarters, variation observatory, and atmospheric-electric observatory.

On April 11 and 12 the observer-in-charge held conferences with the officials of the Cerro-de-Pasco Copper Corporation at Oroya on the subject of the air-pollution resulting from the smelters recently erected at Oroya. Happily the investigations of the scientific staff of the corporation, which are confirmed by an independent inquiry made by the Peruvian Government, show that there is no danger of air-pollution at Huancayo from this source, and consequently no fear of any effect upon the Department's atmospheric-electric work at the observatory.

The observer-in-charge throughout the period covered by this report was Mr. Wilfred C. Parkinson, who was ably assisted by Mr. C. M. Little until May 2 when he returned to the office at Washington. Mr. R. T. Booth, assistant observer, arrived at the observatory on April 22. Pablo Melgar, laborer since the inception of the construction of the observatory, died on June 8, and was replaced temporarily by his brother, Eliseo Melgar.

During the year numerous visitors were welcomed at the observatory and inspected the equipment.

The officials of the Peruvian Government extended many courtesies and arranged free entry for all equipment and apparatus, for all of which grateful acknowledgment is here made. It should also be mentioned that the United States Embassy at Lima forwarded the interests of the observatory in many ways.

Apia Observatory, Western Samoa.—The Department continued to cooperate with the New Zealand Government through the Department of External Affairs and its Honorary Board of Advice and with the British Admiralty in maintaining the Apia Observatory. Mr. Andrew Thomson, Associate Physicist of the Department, continued to serve as acting director, in addition to carrying on the special program of atmospheric-electric observations, for which continuous records of potential gradient have been obtained since May 1, 1922, at a station in the observatory grounds and since October 1, 1923, at the specially constructed laboratory designated "reef house" above the waters of the lagoon (see pp. 241–242 of last year's report). The necessary control observations to determine reduction-factor and calibrations were made regularly and the monthly compilations of resulting data for both stations were kept current. A preliminary report on the atmospheric potential-gradient recorded at the land station during May 1922 to April 1924 was prepared for publication (see abstract, p. 184).

A portable automatic tide-gage, according to the recent design of the U. S. Coast and Geodetic Survey, was supplied and installed at the reef house to provide data for determining the change in the equipotential surfaces caused by the rise and fall of the tides. The gage will be useful in recording the seismic sea-waves which occur in this region of the Pacific.

The magnetic work under Mr. C. J. Westland, assistant director, included, besides the necessary absolute observations and scale-value and base-line controls, the reduction of the hourly scalings for magnetic declination, and horizontal and vertical intensity, to absolute units. The mean values for the year 1923, as determined from the magnetograms, are: declination, $10^{\circ} 16' 3$

east; horizontal intensity, 0.35248 c. g. s. unit; vertical intensity, -0.20440 c. g. s. unit; inclination, $30^{\circ} 06' 6$ south. Although the observatory was situated outside the belt of totality, the special program of observations outlined by the Department for international cooperation in observing possible effects of the total solar eclipse of September 10, 1923, was followed and the resulting data were compiled and forwarded to Washington.

The extensive meteorological program was maintained and new instruments specially designed for the very low range in temperature and pressure at Apia were ordered. The south Pacific weather-reporting system, for which Apia acts as coordinating center, was extended to the eastward to include daily reports from Tahiti and Rarotonga. The 8 stations which now transmit daily weather statements to Apia extend from Tahiti, in longitude 150° west of Greenwich, to Norfolk Island, in longitude 168° east of Greenwich. Although the Samoan Islands are of comparatively small area, nevertheless, on account of their mountainous character, there are large variations in the amount of rainfall received in different districts. Weekly statements of rainfall and weather conditions are supplied by 14 observing stations established in the islands.

The program of upper-air observations instituted in June 1923 was continued and fundamental progress was made in the investigation of over 100 pilot-balloon flights, of which it was possible to follow 60 to heights exceeding 5 kilometers. The greatest altitude reached was 20.5 kilometers (see abstract on p. 184).

Dr. C. Coleridge Farr, a member of the New Zealand Honorary Board of Advice, for Samoa, visited the observatory in December 1923 and in a report published in the New Zealand Journal of Science and Technology he commented favorably on the continued scientific activities of the Apia Observatory, realized largely, as he stated, through the stimulus afforded by the Institution's cooperation with the New Zealand Government. Upon the recommendation of the board of advice, the secretary of the New Zealand Department of External Affairs asked Mr. Thomson, with the consent of the Department of Terrestrial Magnetism, to accept the directorship of the observatory beginning September 1, 1924.

MacMillan North Greenland Expedition.—A radiogram received on November 9, 1923, from Observer R. H. Goddard, in charge of the scientific work done by the Department in cooperation with Dr. MacMillan's North Greenland Expedition of 1923-24 (see p. 242 of last year's report), stated that the magnetograph and potential-gradient electrograph registrations were begun at the Refuge Harbor Observatory (lat. $78^{\circ} 31' N.$, long. $72^{\circ} 27' W.$ of Greenwich) on October 19, 1923. The new observatory, constructed according to the Department's improved design, was superior to the type (see p. 278 of the annual report for 1922) used at Bowdoin Harbor, Baffin Land, in 1921-22. The approximate values of the elements at Refuge Harbor are: declination, 101° west; inclination, $85^{\circ} 8$ north; horizontal intensity, 0.042 c. g. s. unit. Messages received during the winter indicated that the observatory was functioning well. The last radio communication of July 19, 1924, reported that the *Bowdoin* had left winter quarters and would shortly be headed homeward; thus the series of magnetic and electric observations at Refuge Harbor probably covers eight months, namely, from October 1923 to June 1924.

Amundsen's Arctic Expedition.—Observations are being made on this expedition, using a temporary snow house as an observatory. The program includes diurnal-variation observations in declination and in atmospheric potential-gradient. A radiogram giving details of the observational work, received on January 10 by Captain Amundsen at Christiania from Captain

Wisting in command of the *Maud*, stated that at that time 13 complete daily series of electric potential-gradient observations had been obtained since October 1923 by Dr. Sverdrup. The message stated also that the records with the self-recording electrometer during the winter, when referred to Greenwich time, show results closely similar to those obtained on the *Carnegie*, the mean daily value of the atmospheric potential-gradient being about 120 volts per meter and the diurnal range about 50 volts per meter.

Washington, District of Columbia.—The investigations and control of magnetic standards in the Standardizing Magnetic Observatory at Washington were continued. Besides comparisons of instruments before and after field work, reductions and compilations for results of comparisons at observatories were made. Comparisons of standards were obtained since those reported upon in the report for 1923 by Department observers at Batavia (Java), Huancayo (Peru), Teoloyucan (Mexico), and Cheltenham (United States). The comparisons at Cheltenham made during March 18 to 21, 1924, by Messrs. Green and Booth, were for the purpose of controlling the constancy of the standards adopted by the Coast and Geodetic Survey as based on the provisional international magnetic standards adopted by the Department; these comparisons were furthermore made in accordance with the Rome resolution of the International Section of Terrestrial Magnetism and Electricity as noted on page 243 of last year's report, and the results are to be reported upon at the Madrid meeting of the section to be held during next October.

Operation of the experimental atmospheric-electric observatory on the deck of the Laboratory at Washington was continued under the immediate direction of Dr. Mauchly. Daily photographic records of the potential and of the negative conductivity of the atmosphere were about 90 per cent complete; as during last year, there was considerable disturbance caused by the operation of steam shovels in the immediate neighborhood of the laboratory (see p. 148).

Reduction of observatory records.—Excellent progress was made in the final reductions of the magnetic records obtained at the Watheroo Observatory. The work continued in the charge of Dr. Edmonds, who was assisted chiefly by Messrs. W. F. Wallis and C. C. Ennis. The final tabulations for the four years 1919 to 1922 are nearly completed and are being made ready for publication. The mean annual values of the magnetic elements as deduced from the magnetograms for all days at the Watheroo Observatory for the four years are tabulated below:

TABLE 1.—Yearly mean values of magnetic elements at Watheroo Magnetic Observatory (Western Australia), as determined from magnetograms for all days.

Year.	Declination west.	Horizontal intensity.	Vertical intensity.	Inclination south.
	° ' ''	c. g. s.	c. g. s.	° ' ''
1919	4 22.8	0.24925	−0.50780	63 51.4
1920	4 22.1	0.24888	−0.50832	63 54.8
1921	4 21.5	0.24842	−0.50865	63 58.2
1922	4 20.8	0.24799	−0.50885	64 01.1

INSTRUMENT WORK AND BUILDINGS.¹

Classification of work.—The time of the shop personnel was distributed about as follows: one-fifth on the construction of experimental apparatus, one-fifth on the construction of new instruments, one-third on improvements and repairs to observatory and field instruments, and the remainder on build-

¹ From the report of the foreman of instrument shop, C. Huff.

ing improvements, on construction of stock parts for shop, field, and observatory use, on preparation of detailed drawings for new apparatus, and on special work.

New work.—New work completed during the year and in the course of construction at the end of the year was as follows: (1) ionization chambers 7 to 12, completed; (2) ionization collector comparison-chambers 1 to 3, completed; (3) six magnetogram pricklers, completed; (4) earth-inductor attachments for dip circles 171 and 172, completed; (5) construction and installation of collimating system and shutter for azimuth pier, completed; (6) special apparatus for assembling quartz fibers, completed; (7) further design and construction of standard potential-gradient apparatus 6 to 9 for observatory use; (8) five earth-inductor attachments for C. I. W. theodolite magnetometers.

Experimental work.—In addition to the development work on the apparatus used in the investigations on magnetization by rotation, considerable time was given to the design and construction of an earth-resistivity measuring apparatus for field use, the construction of a special device to facilitate the mounting of quartz-fiber systems in bifilar and unifilar electrometers, and to the construction of special quadrants for the necessary investigations of the behavior of Dolezalek electrometers required in the design of the observatory type of atmospheric potential-gradient apparatus.

Improvements and repairs.—Repairs were made as necessary to field instrumental equipment. Improvements made in the main building included a water-supply and waste system for the Langmuir two-stage vacuum pump, rearrangement of the telephone system, rewiring of lighting fixtures to provide live circuits for portable lamps, the installation of door checks, and alteration of room 204 to make it suitable for office use. Good progress was made in constructing the new oak library stacks and their lighting system, for which special units were designed and constructed in the shop; the stacks were one-half completed at the end of June.

Miscellaneous.—A special 40-volt battery of Pye storage cells, together with charging panel, was made up and shipped to Huancayo for use with the radio set installed there. A 3-tube radio receiving set having a wave-length range of about 100 to 20,000 meters was designed and constructed for use at the Watheroo Observatory. A great deal of time was devoted to the preparation and installation of the variometer and electrograph exhibits at the building of the National Academy of Sciences, and to the exhibits at the Administration Building of the Institution at the annual meetings in December.

A plan for future development of planting for the site and for special landscape treatment was considered with an expert of the Department of Agriculture, and planting was begun according to the general treatment recommended by him.

MISCELLANEOUS ACTIVITIES.

Staff conferences.—Biweekly meetings of the investigatory staff, to which visitors were occasionally invited, were held for the discussion of investigational work under way or to be undertaken, progress in such work, reports upon observatory and field operations, development of instrumental equipment, and the results of cooperation in magnetic and electric fields stimulated by the Department's activities. A bulletin regarding personnel, observatory

work, field operations, and other items of interest was issued monthly to all members of the staff.

American Geophysical Union.—An active part was taken in the annual meeting of the Union in Washington during May 1 to 3, 1924, the following serving as officers: Louis A. Bauer, chairman of the Union and vice-chairman of the Section of Terrestrial Magnetism and Electricity to June 30; J. P. Ault, chairman of the Section of Oceanography to June 30; J. A. Fleming, secretary of the Section of Terrestrial Magnetism and Electricity. Suggestions were submitted for the agenda of the Madrid meeting in October 1924 of the International Section of Terrestrial Magnetism and Electricity. The director was appointed one of the delegates to represent the American Geophysical Union at the Madrid meeting of the International Geodetic and Geophysical Union, and Mr. Harradon, on furlough in Europe, was invited to attend that meeting to assist the American delegates as stenographer and translator. Dr. Bauer was elected chairman of the Section of Terrestrial Magnetism and Electricity and Mr. Peters was elected vice-chairman of the Section of Oceanography, both for two years from July 1, 1924.

International Geodetic and Geophysical Union.—Dr. Bauer continued his duties as secretary and director of the Central Bureau of the International Section of Terrestrial Magnetism and Electricity, serving also as chairman of the special Committee on Magnetic Surveys and International Comparisons of Instruments. Mr. Fleming is a member of the Committee on Best Methods, Instruments, and Compilations for Polar-Light Observations. Dr. Mauchly served as secretary of the Committee to Consider and Report on Best Methods and Instruments for Earth-Current Observations.

Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee.—The tabulations of magnetic character-numbers of days for the magnetograms obtained at the Watheroo and Huancayo observatories were prepared and forwarded regularly to Dr. Van Dijk for publication by the Commission.

National Research Council.—In addition to the exhibit prepared for installation in the new building of the National Academy of Sciences and National Research Council referred to below, assistance in connection with committees of the Council and information on special topics, as requested from time to time, were given by Messrs. Ault, Barnett, Bauer, Fleming, Mauchly, and Peters. Dr. Bauer was appointed to serve as a member of the Division on Foreign Relations of the Council.

Exhibits.—The Department took part in several exhibits during the year. These included the annual exhibit held during December 1923 at the Administration Building of the Institution to show some of the chief results and features of investigations conducted in 1923 by the various departments and associates, and an exhibit of scientific apparatus held at Cincinnati during December 27, 1923, to January 2, 1924, at the seventy-fifth anniversary meeting of the American Association for the Advancement of Science.

Upon the request of the Committee on Exhibits of the National Academy of Sciences and of the National Research Council, the Department contributed by a loan of magnetic instruments, to the permanent scientific exhibit installed in April 1924, when the new building of the Academy and Council was occupied and the sixtieth anniversary of the Academy was celebrated. This installation by the Department included a set of magnetic variometers

and an atmospheric potential-gradient apparatus to illustrate visually changes in the Earth's magnetic elements and in the potential gradient of the atmosphere.

Mr. Fleming served during the year as a member of the special Committee on Exhibits of the Institution, appointed by President Merriam, under the chairmanship of Dr. F. E. Wright.

Library work.—Mr. F. E. Brasch, temporarily in charge of the library during the absence of Mr. Harradon, librarian, on furlough in Europe, reports that the total number of books and pamphlets received through June 1924 since the last annual report was 409, making the total number of accessioned publications now in the library over 13,100. The revised and enlarged classification system as prepared by Professor J. D. Thompson, of the National Research Council, was completed (see p. 246 of last year's report). This system was used for all new books and pamphlets received, and excellent progress has been made on the reclassification and rearrangement of the whole library in accordance with the system. Permanent oak library stacks in course of construction will increase the available shelf space some 600 per cent, thus greatly facilitating the early completion of reorganization of the location of books and their classification for reference purposes. Extensive use was made of the privileges accorded by the various governmental libraries, including particularly the Library of Congress and the libraries of the Coast and Geodetic Survey, the Weather Bureau, the Bureau of Standards, and the Geological Survey, in the loan of books and reference works at various times. A list of recent publications concerned with those subjects of special interest to the Department, viz., terrestrial and cosmical physics and electricity, was prepared regularly and published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. Mr. Brasch served as treasurer and assistant secretary of the newly formed History of Science Society.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Magnetic results obtained on the *Carnegie* during Cruises IV, V, and VI, 1915-1921.¹
J. P. Ault. Phys. Rev., vol. 22, 526 (November 1923).

The final results of magnetic observations made on the *Carnegie* during her cruises IV, V, and VI, 1915-1921, prepared for publication as one of the series bearing the general title *Researches of the Department of Terrestrial Magnetism*, were briefly summarized.

The analyses of the harbor and sea swings of the *Carnegie* on all cruises, 1909-1921, show that the residuals or so-called "ship deviations" are not of sufficient magnitude to be taken into account. A discussion of the magnetic chart-differences shows a steady improvement in the ocean magnetic charts since the beginning of the ocean survey of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

The data given in the special report by W. J. Peters on the final magnetic results obtained on board the power schooner *George B. Cluett* during a cruise along the Labrador coast and into Hudson Bay and return in the summer of 1914 were also discussed.

A preliminary discussion of the magnetic secular variation over the ocean areas, as based upon all the ocean magnetic results to date, shows that much valuable information regarding the secular variations over the oceans has

¹ Presented before the meeting at Pasadena of the American Physical Society, September 18, 1923.

been obtained. It also emphasizes the lack of such information in the important north and south polar regions and in certain parts of the major oceans, particularly in those parts of the Atlantic and Indian Oceans where the annual changes show the greatest variation.

It is hoped that the ocean magnetic and electric survey work of the *Carnegie* may be resumed at an early date, to round out and complete the work already done, by filling in areas where observations are few and scattered, and to make of permanent value the accuracy of the results already obtained by increasing the number of secular-variation stations.

Effects of a total solar eclipse on the Earth's magnetic and electric fields. J. P. Ault. *Phys. Rev.*, vol. 22, 526-527 (November 1923).

An abstract of this paper is given on page 247 of the Director's annual report for 1923.

Report on magnetic observations by the Carnegie Institution of Washington during the total solar eclipse of September 10, 1923.¹ J. P. Ault. *Terr. Mag.*, vol. 29, 1-12 (March 1924).

This paper presents a report on special magnetic observations made by the Carnegie Institution of Washington at Point Loma and Mount Wilson, California, and at Guatemala City, Guatemala, during the solar eclipse of September 10, 1923. At Point Loma, magnetic declination, horizontal intensity, and inclination observations were made, while at the other two stations only declination observations were made.

Methods and instruments similar to those used during previous eclipses were employed, and the eclipse effects on the Earth's magnetic field were similar to those previously observed. The usual diurnal variation in the Earth's magnetism was interrupted, the change amounting to from 1'5 to 3' in declination, 60γ in horizontal intensity, and 1'5 in inclination. A complete analysis and discussion must await the receipt of data from other observatories located near the belt of totality.

Note on a preliminary discussion of the magnetic observations of the Coast and Geodetic Survey during the total solar eclipse of September 10, 1923. J. P. Ault. *Terr. Mag.*, vol. 29, 72 (June 1924).

The Coast and Geodetic Survey magnetic results obtained at Lompoc, California, during the total solar eclipse of September 10, 1923, as given in the March 1924 issue of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, were compared with simultaneous ones obtained by the Department of Terrestrial Magnetism at Mount Wilson and at Point Loma (see preceding abstract). The Lompoc declination values for September 11 agree almost exactly with those at Mount Wilson; those for September 10 agree until the time of totality, after which the Mount Wilson values gradually increase more rapidly than the Lompoc values until at 24^h G. M. T. the separation amounts to nearly 1 minute. The values for September 9 agree from 18^h to 20^h G. M. T., when a magnetic-disturbance effect began. This disturbance effect appeared to be nearly 2 minutes greater at Mount Wilson than at Lompoc between 20^h and 22^h G. M. T., after which the values agree again. This would seem to confirm previous indications that disturbance effects are appreciably modified by change in altitude. This close agreement between the Lompoc results and those obtained at Mount Wilson confirms the conclusions previously reached² regarding the 1923 eclipse magnetic variation.

The declination results obtained at the five observatories of the Coast and Geodetic Survey give apparent eclipse magnetic variations ranging

¹ Based on paper presented before the Philosophical Society of Washington, December 15, 1923.

² *Terr. Mag.*, vol. 29, 1-12 (March 1924).

from 1 minute at Porto Rico, Cheltenham, and Honolulu to 2 minutes at Tucson and $3\frac{1}{2}$ minutes at Sitka. The effect in the horizontal and in the vertical intensities at the five observatories, if present, was quite small. The magnetic disturbance effect on September 9, the day before the eclipse, was not apparent at Honolulu and was greatest at Cheltenham and at Tucson.

Surveying the oceans with the non-magnetic yacht *Carnegie*. J. P. Ault.

This was the subject of a radio talk broadcast on May 21, 1924, under the auspices of the Smithsonian Institution, from the station (WRC) of the Radio Corporation of America at Washington, D. C. A general description of the non-magnetic survey-yacht *Carnegie* and a popular account of her work were given. The history, purposes, and needs of ocean magnetic and electric surveys and the contributions of such surveys in advancing geographic knowledge, commerce, and navigation, and investigations concerned with the magnetism and electricity of the Earth and its atmosphere, were briefly summarized.

Cosmic effects in terrestrial magnetism and atmospheric electricity, and their physical bearings.¹ Louis A. Bauer. *Phys. Rev.*, vol. 23, 303 (February 1924).

It is shown that fluctuations in the Earth's magnetism, the Earth's electrification, earth-currents, and polar lights all synchronize very closely with fluctuations in the activity of the Sun, as indicated by the variability in sun-spottedness during the well-known solar cycle of about 11 years.

While this synchronism with solar phenomena has been known definitely as regards the Earth's magnetic changes, earth-current disturbances, and frequency of polar lights, it has only now become known with a high degree of certainty that atmospheric electricity passes through cyclic changes corresponding with the sun-spot cycle.

It is also found that a close relation exists at the Ebro Observatory, Tortosa, Spain, between the diurnal and annual variations of the electric currents continually flowing in the Earth's crust and the rate of fluctuation during the day and the year in the potential gradient of atmospheric electricity or in the Earth's negative electric charge.

These new facts, if confirmed at other stations, will have their important bearings on theories concerning the origin and maintenance of the Earth's electric charge and of the Earth's electric currents, the disturbances in which seriously interrupt at times telegraphic and cable transmission.

Relations between solar activity and the Earth's magnetic and electric phenomena.² Louis A. Bauer.

Besides indicating some of the relations between solar activity and the Earth's magnetic fluctuations, this paper made the special attempt to show how atmospheric electricity and earth-currents vary during the sun-spot cycle. Diagrams respecting the earth-effect on sun-spottedness were also exhibited.

The relation between solar activity and atmospheric electricity. Louis A. Bauer. *Nature*, vol. 112, 686 (November 10, 1923); (abstract) *Physik. Ber.*, vol. 5, 179 (February 1, 1924).

A brief description is given of queries raised by Dr. Chree as to the effect of sun-spot activity on the secular change of the Earth's magnetism and with regard to a difference in the method or formula used by him and by the author when investigating a possible relationship between solar activity and atmospheric electricity (see abstract, pp. 249-250 of last year's report).

¹ Presented at the Cincinnati meeting of the American Physical Society, December 28, 1923.

² Presented before Cincinnati meeting of Section D (Astronomy) of the American Association for the Advancement of Science, December 28, 1923.

As a result of the investigation, the desirability of multiplication of atmospheric-electric stations, where every possible care will be taken to insure continuity of strictly comparable data for as long a period as possible, is emphasized. It is particularly requisite, among other precautionary measures, that more frequent and more extensive controls of the factor for reducing potential gradients to an infinite plane be made than is at times the case.

Relations between the diurnal and annual variations of earth-currents, terrestrial magnetism, and atmospheric electricity. Louis A. Bauer. *Terr. Mag.*, vol. 28, 129-140 (December 1923).

An investigation is made as to correlations in the diurnal and annual variations of earth-currents with those of terrestrial magnetism and atmospheric potential-gradient, as based on the observations at the Ebro Observatory, Tortosa, Spain, for the magnetically quiet days during the five-year period 1914-1918.

It is found that the diurnal and annual variations of the horizontal components (X towards north and Y towards east) of terrestrial magnetism are of such a character, quantitatively and qualitatively, as to indicate that only to a certain extent may they be the direct electromagnetic effects of the observed corresponding earth-currents (W towards west and N towards north). On the other hand, there is a high probability that the observed earth-currents may be the combined result of a varying magnetic field and a varying electric field as indicated by the rate of variation in terrestrial magnetism and atmospheric electricity during the day and year. The correlation between the variations of earth-currents and the rate of variation, or time-gradients, of the atmospheric potential-gradient is found to be even higher than that for the time-gradients of terrestrial magnetism, both as regards the diurnal variation and the annual variation. The investigation is to be continued with the aid of additional data obtained at the Ebro Observatory in Spain and the Watheroo Observatory in Western Australia.

The magnetic Earth and the electric atmosphere.¹ Louis A. Bauer.

Through the lines of magnetic force, which envelop our Earth like a "gossamer garment" and extend far out into illimitable space, and through the lines of electric force permeating our atmosphere, we are realizing more and more that there are other bonds of union than those of gravitation between the Earth and Sun and our sister planets. Every moment there are being registered at observatories, designed for the purpose, magnetic and electric impulses, the import and cosmic significance of which we are gradually beginning to decipher. With truly prophetic vision, Orpheus declared "with the lodestone you can hear the voices of the Gods and learn the mysterious things of heaven."

These lines of magnetic and electric force, with the aid of which the Earth traps and captures the corpuscular electric charges continually being sent out by the Sun, recent investigations show also envelop the Sun, as indicated, for example, by the coronal streamers seen during total solar eclipses. It would seem that just as polar lights visualize for us the lines of magnetic force of our planet at altitudes of several hundred miles, so does the solar corona visualize the lines of magnetic force at high altitudes above the Sun's surface. And the belief is becoming current that every large rotating mass is endowed with a magnetic field and its attendant lines of magnetic force. We must then not imagine that the interacting agencies mutually influencing the members of our solar system are bounded by the surfaces of the bodies we immediately behold. Fluctuations in the Earth's magnetism and in its

¹ Illustrated lecture given before the Royal Canadian Institute, Toronto, January 5, 1924.

electrification, disturbances in the electric currents continually circulating in the Earth's crust, and the occurrence of polar lights, all are found to synchronize closely with solar changes, as indicated by variability in sun-spot-tedness.

It is also coming more and more to be believed that the solution of the problems concerned with the origin of the Earth's magnetic field or of its electric charge is bound to reveal to us hitherto unknown properties of matter, or to advance our knowledge as to the physical conditions prevailing in regions—deep down in the Earth or high up in the atmosphere—to which we have at present no means of access. Thus the studies of the Earth's magnetic and electric phenomena, aside from their practical importance, possess high interest for the physicist, the geologist, and the astronomer.

The subject was elaborated in a popular manner, and numerous lantern slides were shown to illustrate the practical and theoretical results achieved with the aid of observational data, in the obtaining of which Canada has had a prominent share. The extension of the observational work at present being carried out by various governmental services, covering areas embracing both the Magnetic North Pole and the focus of greatest magnetic intensity, promises to play a preeminent part in the definite settlement of mooted questions of practical and theoretical import, not only in terrestrial magnetism, but also in atmospheric electricity and radio-telegraphy.

The organization and aims of the American Geophysical Union.¹ Louis A. Bauer. Bull. National Research Council, vol. 7, 7-18 (January 1924).

Report of the Rome meeting of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union.² Louis A. Bauer. Bull. National Research Council, vol. 7, 117-118 (January 1924).

Summary of results of a recent analysis of the Earth's magnetic field for 1922.³ Louis A. Bauer. Bull. National Research Council, vol. 7, 126-127 (January 1924).

Progress reports of the Committee on Relations between Terrestrial Magnetism, Terrestrial Electricity, and Solar Activity.³ Louis A. Bauer. Bull. National Research Council, vol. 7, 107-110 (January 1924).⁴

These reports, the first of which is published in the Transactions of the American Geophysical Union, Fourth Annual Meeting, April 1923 (reference as above), show progress in the fields of concern to the committee during the years 1922 to 1924, and may be briefly summarized as follows:

(a) The accumulation of data and the development of researches on measures of solar activity, magnetic activity, and electric activity. Professor Wolfer's data indicates it is not yet possible to state definitely whether 1923 was the year of minimum sun-spot activity or whether the minimum will occur during 1924. Dr. Bauer, of the Department of Terrestrial Magnetism, has published the chief results of investigations on correlation factors and relationships as follows: (1) Relations between the diurnal variation and annual variation of earth-currents, terrestrial magnetism, and atmospheric electricity; (2) correlations between solar activity and atmospheric electricity (see abstracts on pp. 169 and 173).

(b) Developments in the study of the magnetic polarity of sun-spots as reported upon by the Mount Wilson Observatory in 1922 to 1923, with the indication of an approaching new cycle. The new sun-spot groups showed a reversal in magnetic polarity or a return to magnetic conditions of sun-spot groups prior to the beginning of the present cycle, as though the magnetic phenomena of sun-spots were subject to a periodicity of 22 years instead of the

¹ Presented at the opening general session of the annual meeting of the American Geophysical Union, Washington, April 17, 1923.

² Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

³ Presented at the annual meetings of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923, and May 2, 1924. Members of Committee: Louis A. Bauer, chairman, C. G. Abbot, R. L. Faris, G. E. Hale, and C. F. Marvin.

⁴ The report presented at the annual meeting in 1924 is not yet published.

customary cycle of about 11 years. There are indications that the Earth's magnetic and electric phenomena are also subject to longer periods than the usual sun-spot cycle.

(c) Recent solar-radiation observations by the Smithsonian Institution and modifications of the apparatus and methods employed at the Institution's two stations at Mount Harqua Hala, Arizona, and at Mount Montezuma, Chile. In general, the solar radiation has been well below normal. Dr. Abbot has made some progress in the investigation of the variations of the Sun's visible features associated with variations in solar radiation.

(d) Investigations on correlations between solar activity and meteorology, as continued by Professor Marvin, of the U. S. Weather Bureau. If the synchronism between terrestrial magnetism, auroral phenomena, etc., and sun-spots is shown to be very close, it may be possible to utilize some of the old records in terrestrial magnetism to extend or possibly confirm the general accuracy of sun-spot data in the early centuries.

The Earth and Sun as great magnets.¹ Louis A. Bauer. Report 96th Meeting Eastern Association of Physics Teachers, 14-18 (1924).

The cause of the Earth's magnetism is still one of the great problems of terrestrial physics to be solved. Next to gravitation, eminent physicists have characterized terrestrial magnetism as one of the most puzzling of natural forces, and, indeed, it is the belief of some that planetary gravitation and magnetism are intimately related. Furthermore, whatever theory may be formulated to account for the Earth's magnetic or its electric field, it is necessary to introduce somewhere a hypothesis implying new properties of matter, or changes in the classical laws of electro-dynamics, or physical conditions below or above the Earth's surface, of which but little is known at present.

The difficulties encountered in the formulation of any theory of the Earth's magnetism are in part mathematical, in part geometrical, because of the sphericity of the Earth-magnet whereby limitations are set as to the strength of magnetization which may be imparted by a system of electric currents, for example, circulating outside and around the Earth as a magnetizable core. But the chief difficulties arise from the physical conditions involved. A limitation is also set, since deduction must at present be drawn from magnetic observations made exclusively on the surface of the Earth. Until similar observations above and below the surface are obtained with requisite accuracy, it is not possible to determine the precise distribution of the magnetic and electric systems, inside and outside the Earth, which give rise to the observed magnetic field.

Fortunately there are three bodies, vastly differing from one another in their physical constitution—the Earth, a comparatively cold body, the Sun, a hot body, and the atmosphere, a tenuous body—whose magnetic and electric fields may come within the scope of investigations and help in the formulation of theoretical views. The direction of the magnetic axis of each one of these bodies is related in the same way for all three to the direction of rotation of the body, and is inclined to the axis of rotation, namely, at present, about 11.5° for the Earth, about 14° for the atmosphere, and about 6° for the Sun. The strength of the magnetic fields of these three bodies, at their magnetic poles, for example, may be expressed approximately by a formula in terms of a physical factor f , the angular velocity of rotation ω , the radius r , and the density of the body D , thus: $F = f\omega r^2 D$. The magnetic field so expressed has thus far defied laboratory detection because of limitations of the size and speed of rotation of bodies that may be experimented with, but it becomes readily appreciable when dealing with a body of mass, size, and angular velocity of rotation comparable with those of a member of our solar system. If this formula holds universally, Jupiter, for example, would be enveloped

¹ Address before the 96th meeting of the Eastern Association of Physics Teachers at Boston, December 8, 1923.

by a magnetic field of about the same strength as that of the Sun—say, about 70 times that at the Earth's magnetic poles.

The chief results on the composition of the Earth's magnetic field thus far obtained through the analysis (see abstract on pp. 229, 230 of the annual report for 1923) of accumulated data were given in detail. Hypotheses and possible conclusions that may be inferred from consideration of these results in connection with the formula above given for the strength of the magnetic field were briefly reviewed. The most hopeful avenue of approach to the establishment of a theory to account for the observed magnetic and electric fields of the Sun-magnet and of the Earth-magnet appears to be by means of the experiments which Nature itself performs on these magnets, as revealed by the countless changes ever going on in their fields of force.

Correlations between solar activity and atmospheric electricity.¹ Louis A. Bauer. *Terr. Mag.*, vol. 29, 23-32 (March 1924).

It has been known for many years that certain fluctuations of the Earth's magnetic field vary appreciably with sun-spottedness. The first one to have raised the question whether atmospheric electricity also might be subject to a sun-spot cycle variation appears to have been Dr. A. Wislizenus, a physician of St. Louis, Missouri, who for 12 years, 1861-1872, made relative measurements of the atmospheric potential gradient six times daily. As this question is conceded to be of paramount importance in theories of the origin and maintenance of the Earth's negative electric charge, it was thought well worth while to make a preliminary examination of the available atmospheric-electric data, especially those obtained since the method of absolute measurements of the potential gradient was introduced. In view of the many disturbances to which atmospheric-electric results are subject, it was necessary to restrict the investigation to the so-called electrically undisturbed days. These are "fine-weather days," or days of no negative potential and no pronounced electric disturbances. The chief conclusions reached at present as based upon results at observatories where atmospheric-electric data have been obtained for a sun-spot cycle, or longer, are as follows:

1. During the past two sun-spot cycles (1901-1923), the atmospheric potential gradient and the amplitudes of the diurnal variation and of the annual variation generally increased with increased sun-spot frequency; the increase in the particular electric element considered was about 20 to 25 per cent, on the average, for a change of 100 in the sun-spot number. The correlation coefficient, on the average, was about 0.75.

2. If any reliance may be placed on the very few available series of atmospheric-electric observations made prior to 1901, hence before the period of absolute observations, then there are some indications that during two periods, centering about 1855 and 1889, the reversed relationship to that mentioned in (1) applied. The forthcoming sun-spot cycle will afford opportunity to examine into this matter more thoroughly.

3. An interesting correlation is exhibited by the atmospheric-electric and magnetic data for 1893, which unite in showing a decrease in the electric and in the magnetic activity at the time of maximum sun-spot frequency.

4. Interesting correlations are found between certain phenomena of terrestrial magnetism, earth-currents, and atmospheric electricity, that probably must be referred to a joint effect of solar activity.

In view of the theoretical bearings of the questions raised and their general interest, it is very much hoped that the present results will stimulate those in charge of atmospheric-electric stations to use all possible care to insure continuity of strictly comparable data for as long a period as possible.

¹ Presented before the Philosophical Society of Washington, May 17, 1924.

Concerning the variations of atmospheric electricity and vertical currents. Louis A. Bauer. *Science*, vol. 59, 378-379 (April 25, 1924).

The early history of terrestrial magnetism in the United States, with special reference to the work of Dr. John Locke of Cincinnati.¹ Louis A. Bauer. *Science Monthly*, vol. 18, 625-627 (June 1924).

This paper gives an historical account of the pioneer magnetic surveys made by Dr. John Locke during 1838 to 1848. These surveys extended from the southern part of Kentucky to the northern side of Lake Superior and from the State of Maine to some distance beyond the Mississippi, and were conducted almost entirely at private expense. His observations gave the first indication of the American focus of greatest magnetic intensity. His unselfish devotion and many valuable contributions to the science of terrestrial magnetism, as well as his additions to knowledge in various other sciences, were notable.

List of recent publications. F. E. Brasch. *Terr. Mag.*, vol. 28, 150-152 (December 1923); vol. 29, 53-56 (March 1924); 93-96 (June 1924).

These lists constitute a bibliography of current literature, with brief notes under the classifications (A) terrestrial and cosmical magnetism, (B) terrestrial and cosmical electricity, and (C) miscellaneous, the last containing references to subjects allied to those under (A) and (B).

Sunshine record at Apia, Samoa, for the year 1921. H. M. W. Edmonds. *Apia Observatory Report for 1921*, 50 (1923).

This gives a summary and tabulation, with notes, of the sunshine records obtained at the Apia Observatory during the year 1921.

The Bermuda magnetic anomaly.² H. W. Fisk. *Bull. National Research Council*, vol. 7, 118-120 (January 1924).

An abstract of the matter contained in this paper is given on pages 253 to 254 of the Director's annual report for 1923.

A differential method for deriving magnetometer deflection-constants. H. W. Fisk and C. R. Duvall.

For the computation of the horizontal component of the Earth's magnetic field from the observed angle of deflection of one magnet by a second in Lamont's first position, a factor, intrinsically a function of the dimensions of the magnets employed, is required to correct for these finite dimensions. The so-called "distribution-coefficients" concerned in this factor are generally determined through a rather tedious computation depending on the data observed at three deflection-distances. Theoretically the ratio of the sines (or the difference of the logarithmic sines) of the observed angles of deflection for any two distances is constant for a given instrument and pair of magnets; differential methods based on this theoretical condition are developed which simplify the computations required.

The magnetometer constants and the resulting corrections of the instrument on standard depend directly on the values of the distribution-coefficients employed in the computation, and these, in turn, are practically linear functions of the sine-ratios connecting the observed deflection-angles. Such instrumental corrections on standard arising from differences in the observed values of these sine-ratios may be expressed by the formula

$$\Delta H/H = A \Delta \log S_{21} + B \Delta \log S_{31}$$

¹ Presented before Section L (History of Science) of the American Association for the Advancement of Science, Cincinnati, December 29, 1923.

² Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

in which A and B are numerical quantities easily evaluated and may be used without change for all instruments of like type for which the deflection-distances have been cut, using the same template. The symbols S_{21} and S_{31} signify the ratio of the sine of the deflection-angle at the second distance to that of the first and at the third distance to that of the first, respectively.

The more exact form of the distribution-factor, $(1+Pr^{-2}+Qr^{-4})$, is found to be less satisfactory in practice than the simpler form $(1+P'r^{-2})$, where magnets have been designed to make the value of Q as small as possible (theoretically zero), on account of the greater sensitiveness of the factor with P and Q to changes in the sine-ratios. The paper includes numerical examples and tabulations to show the application of the formula derived to the determination of distribution-coefficients, constants, and corrections on standard for a number of C. I. W. instruments.

Results of comparisons of magnetic standards at observatories in 1922 to 1924. J. A. Fleming.

This report summarizes the final results of comparisons obtained during 1922 to June 30, 1924, by Messrs. W. C. Parkinson, D. G. Coleman, F. C. Brown, J. W. Green, and R. T. Booth, of the Carnegie Institution of Washington, at 30 observatories, namely: Algiers, Algeria; Apia, Samoa; Batavia, Java; Christchurch, New Zealand; Cheltenham (twice), United States; Coimbra, Portugal; De Bilt, Netherlands; Ebro, Spain; Eskdalemuir, Great Britain; Greenwich, Great Britain; Helwan, Egypt; Huancayo, Peru; Kakioka, Japan; Kew, Great Britain; La Quiaca, Argentina; Mount Lofty (Adelaide Observatory), Australia; Pilar, Argentina; Potsdam, Germany; Rome, Italy; Rude Skov, Denmark; San Fernando, Spain; Sodankylä, Finland; Teddington (National Physical Laboratory), Great Britain; Teoloyucan, Mexico; Toolangi, Australia; Uccle, Belgium; Val Joyeux, France; Vassouras, Brazil; Watheroo (twice), Australia; and Washington (Standardizing Magnetic Observatory), United States (twice).

The results are tabulated as in previous reports¹ on comparisons of observatory magnetic standards; the methods followed are described. For those observatories where comparisons have been made before, tabular summaries showing mean corrections on provisional International Magnetic Standards¹ from all comparisons are given. Results from indirect comparisons through observations of other organizations are given also for the standards of Agincourt, Canada; Meanook, Canada; Ottawa, Canada; and San Miguel, Azores.

In accordance with the resolution (see p. 243 of last year's report) adopted at the 1923 meeting of the American Geophysical Union, designating the Cheltenham Magnetic Observatory of the U. S. Coast and Geodetic Survey and the Standardizing Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, working in conjunction, as the observatories in the United States to function for international comparisons of magnetic instruments and for national comparisons, intercomparisons of the standard instruments of the two organizations were obtained in March 1924. The results show good agreement with values from the six comparison-series obtained during 1905 to 1918, and thus indicate maintenance of the provisional International Magnetic Standards within requisite limits. A series of indirect comparisons of the Survey standard in

¹ Louis A. Bauer and J. A. Fleming, Results of comparisons of magnetic standards, 1905-1914, Res. Dep. Terr. Mag., vol. II, 211-278 (1915). Louis A. Bauer and J. A. Fleming, On magnetic standards and comparisons of the Department of Terrestrial Magnetism, Bull. 3, Sect. Terr. Mag. and Electr., Internat. Geod. Geophys. Union, 84-97 (October 1923). J. A. Fleming, Results of comparisons of magnetic standards, 1915-1921, Res. Dep. Terr. Mag., vol. IV, 395-475 (1921).

inclination through comparisons of a new Survey inductor at the Standardizing Magnetic Observatory, also show close agreement with the earlier results.

Reports of the Committee on Magnetic Standards and Instruments, and Methods of Aerial Magnetic Measurements.¹ J. A. Fleming. Bull. National Research Council, vol. 7, 110-115 (January 1924).²

These reports cover progress during the two years ending with April 1924 in the fields of concern to the committee under the headings: (a) Comparison of magnetic and electric methods for determining the horizontal intensity of the Earth's magnetic field; (b) maintenance of standards provisionally adopted by the Carnegie Institution of Washington; (c) comparisons of magnetic standards at observatories; (d) magnetic standards of the United States Coast and Geodetic Survey; and (e) instruments and methods for aerial magnetic measurements.

An abstract of progress through 1923 under (a) and (b) is given on pages 256 to 258 of last year's report. Since that report N. Watanabe and T. Kawamura have published³ the final results of the data obtained from comparisons between Watanabe's electric instruments and magnetic instruments. The agreement of his electric magnetometer with the provisional International Magnetic Standard (I. M. S.) of the Carnegie Institution of Washington, the Schuster-Smith magnetometer, and the Carnegie Institution of Washington sine-galvanometer is improved by correcting for the difference between the international ampere and the absolute ampere, making the correction for his instrument on the others $0.00009H$ less. Dr. Chree, reporting upon comparisons between the Schuster-Smith magnetometer and the Kew Observatory standard magnetometer from three series in 1921, 1922, and 1923, shows the average difference (Kew-Schuster-Smith) to be only $-0.00004H$ (applying for 1922), although there is apparently a slight progressive change with time. Utilizing the 1922 C. I. W. comparison data at Kew, the resulting value for (I. M. S. - Schuster-Smith) is $+0.00008H$, in fair agreement with the value directly determined by C. I. W. comparisons at Teddington in 1922, namely, $-0.00015H$. Dr. Watanabe's comparisons at Lukiapang, China, in November 1922, between his electric magnetometer and the Observatory magnetometer Elliott No. 49 also give an excellent check on values of (I. M. S. - Watanabe electric magnetometer) through comparisons on I. M. S. at Lukiapang in 1917, the resulting correction on I. M. S. being $-0.00021H$ as against the actual value observed at Kakioka in 1922 of $-0.00031H$. Thus it is again shown that there is substantial agreement between magnetic and electric instruments well within the limits of all practical requirements.

For brief accounts of matter reported under (c), see page 175. Further comparisons of observatory standards are reported by Dr. Chree with Kew Observatory for Greenwich, for Valencia, for Eskdalemuir (indirect in inclination only), and for the observatories of the Trigonometrical Survey of India through comparisons in 1922 at Kew of a survey magnetometer and later comparisons of the latter at the observatories in India. Additional results affording indirect comparisons with I. M. S. were reported by Dr. Melander between Potsdam and Sodankylä. Mr. H. Knox-Shaw, of the Helwan Observatory, indicates the necessity of inertia control at Helwan through discussion of the 1922 results obtained by the Carnegie Institution of Washington. Dr. Maurain advises that the substitution of an earth inductor at

¹ Presented at the annual meetings of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923, and May 2, 1924. Members of Committee: C. G. Abbot, J. P. Ault, S. J. Barnett, L. J. Briggs, J. A. Fleming, chairman, and N. H. Heck.

² The report presented at the annual meeting in 1924 is not yet published.

³ N. Watanabe and T. Kawamura, The measurement of the horizontal intensity of the Earth's magnetic field with portable electric magnetometers, Jap. Jour. Astron. Geophys., vol. 1 (1924).

Val Joyeux for the dip circle previously used and its comparison with the dip circle shows this new observatory standard in inclination to be in exact agreement with the provisional I. M. S.

Under (d) the reports show excellent maintenance and control of standards for the five observatories of the United States Coast and Geodetic Survey, all observatory and field instruments being standardized at the Cheltenham Observatory.

Referring to (e), the reports indicate that the rapid development of radio in various ways as an aid to aerial navigation, especially over land over well-controlled airways, makes the practical need for developing magnetic instruments for use on aircraft increasingly less vital. Theoretical requirements for research work in terrestrial magnetism will call for instruments of high precision because of the smallness of the changes in the magnetic elements to be expected with changes in altitude attainable with present methods of aerial exploration. Such measurements must be controlled also by simultaneous observations at the Earth's surface to eliminate uncertainties arising from diurnal variation and from abnormalities resulting from cosmical or other phenomena. Thus any real contribution to this investigation apparently must come from more or less indirect methods in view of present instrumental limitations and of the limited distances from the Earth's surface which can be attained. The most promising instrumental development would appear to be in apparatus suitable for automatic registration in unmanned carriers, despite the considerable difficulty presented of making provision for automatically indicating orientation with precision at all times. Some progress may be expected by observations continuing over a long period and the discussion of second differences in the magnetic variations for land stations situated not far apart but at greatly different altitudes.

Attention is called to the earth-inductor compass as designed at the U. S. Bureau of Standards originally for aircraft and found to give quite satisfactory service in actual use. It has been tested also on seagoing vessels and found to work well, having the following advantages for use at sea: (a) flexibility of installation in that the master compass can be placed where the ship's magnetic influence is least, aloft if necessary, while duplicate indicators can be installed wherever desired; (b) freedom from roll-and-pitch error, as indicated on a sea-test when the indicator of the earth-inductor compass was stationary, although the ship's magnetic compass was oscillating 2° or 3° ; (c) freedom from lag, since on sudden change of course the indicator moves immediately and without oscillation.

Scope of work at the observatories of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.¹ J. A. Fleming. *Phys. Rev.*, vol. 23, 303 (February 1924).

Because of the unsatisfactory distribution of magnetic observatories, particularly in the southern hemisphere, and the general lack of provision for the study of atmospheric electricity, earth-currents, and like geophysical and cosmical phenomena involved in the problems in terrestrial magnetism, the Carnegie Institution of Washington has authorized the establishment of magnetic and electric observatories where complete programs of work in these subjects may be carried out. Two such completely equipped observatories have been erected, one near Watheroo, Western Australia, and the other near Huancayo, Peru. There is also a temporary electric observatory on the deck of the Department's laboratory in Washington, D. C., which is primarily intended for experimental purposes. In addition to these permanent observa-

¹ Presented before the meeting of the American Physical Society, Cincinnati, December 29, 1923.

tory stations, temporary observatory stations for special studies are established as opportunity offers and as results of investigations indicate desirable. The building and instrumental equipment, the scope of automatic records obtained, and detailed particulars are given for the different classes of work enumerated above, together with a brief account of the desiderata essential in the selection of sites and the conditions for operation.

On determination of magnetometer constants.¹ J. A. Fleming. Phys. Rev., vol. 23, 304 (February 1924).

This paper discusses in detail the methods of determining the constants required for magnetometers using the magnetic method to observe the intensity of the Earth's magnetic field, and the corrections of such instruments on standards in magnetic declination, inclination, and horizontal intensity. So-called "absolute constants" may be determined with certain precision by physical measurements, but it is an open question as to whether dependence may not as well be placed upon constants determined relatively only by comparison observations with standard instruments at base-stations.

Possible changes with time in the values of certain of the constants are of interest. The discussion of numerous determinations of the absolute constants for many C. I. W. magnetometers shows that with appropriate control a high degree of constancy may be expected, even under the difficult and unusual transportation conditions so often encountered in the field, except for changes of the moment of inertia of the oscillating magnet and its suspension arrangements. Thus for certain types of instruments it has been found that under field conditions a change in the inertia equivalent to a change in the horizontal intensity of as much as 0.0004 part may occur in the course of a year's work. Redeterminations of the moment of inertia after long field trips show surprising agreement between observed inertia-changes and observed changes in the corrections of the instruments on adopted standards of intensity. Fortunately, this change, doubtless arising from oxidation, is found through extensive control work at different stations to take place, for the instrument used, linearly with time at least well within the limit of requisite field accuracy, namely, 1 part in 5,000.

Those constants concerned with the deflection observations (the deflection-distances used being mechanically fixed on the brass deflection-bars) for which there heretofore has been some question as to possible serious variation with time are the "distribution-coefficients" defined by the factor $(1 + Pr^{-2} + Qr^{-4} + \dots)$, in which r is the deflection-distance. Consideration of the formulæ involved indicates that any such variation should be small for properly seasoned permanent magnets. This conclusion is verified by compilations from deflection observations for three deflection-distances for many magnetometers of various types used by the Department during 1907 to 1924 at observatory and field stations. Groupings of long series of field results obtained on campaigns in which unusually difficult traveling conditions were encountered and for widely differing values of intensity indicate the distribution-coefficient factor to be independent also of change in the value of intensity. The sources of inaccuracy in ordinary field work are discussed in detail.

Natural electric currents in the Earth's crust.² O. H. Gish.

Sir Humphrey Davy (1820) first postulated electric currents in the Earth as the primary cause of terrestrial magnetism. P. Barlow and Christie a few years later strengthened this view with experiments on models. Fara-

¹ Presented at the meeting of the American Physical Society, Cincinnati, December 28, 1923.

² Presented before the Washington Section of American Society of Mechanical Engineers, Washington, October 18, 1923.

day (1831 to 1832) and Becquerel (1844) made unsuccessful attempts to detect electric currents in the Earth. W. H. Barlow (1847), while in charge of British telegraph lines, first observed earth-currents. Many observations on telegraph lines, especially at times of magnetic storms, followed.

The first continuous records on experimental lines, at Greenwich, were obtained (1865-1867) and discussed by G. B. Airy, who thought that magnetic variations were caused by earth-currents. Other experimental installations yielding continuous records followed. Those at Berlin (1883 to 1888) and at the Ebro Observatory (since 1910) are outstanding. The former, discussed by Weinstein, and the latter, discussed by Bauer, show qualitative agreement in the diurnal variation and seem to indicate that the north-south earth-current component is caused by the east-west magnetic variations, but that the east-west earth-current variations produce the north-south magnetic variations. The earth-current measuring system installed at Watheroo (1923) by the Department of Terrestrial Magnetism illustrates the method. This system has a promising location and has a number of new features which were described (see p. 180).

Of the various theories the outstanding one is that of Balfour-Stewart and Schuster as developed by Chapman, in which quantitative relationships between the magnetic potential and the earth-current diurnal variation are developed. These show fair agreement with fact, and promise to give direction to future investigations.

Preliminary earth-resistivity measurements on the site of the Department of Terrestrial Magnetism at Washington, D. C. O. H. Gish.

For measuring the resistivity of the Earth in the vicinity of earth-current lines the method of Wenner as modified by McCullom and used by him in electrolysis surveys seemed most promising. Preliminary measurements on the grounds of the Department of Terrestrial Magnetism at Washington, to test the method were made in November and December 1923 with a McCullom "earth-current meter" kindly loaned by the U. S. Bureau of Standards. The tests show that with some modification the apparatus and method are suitable for this purpose, and the results obtained are of some interest in themselves.

Thus, using the Bureau's standard cantilever electrode in four 2.5-inch holes at the corners of a 10-foot square, 116 determinations gave a mean resistivity of 28,100 ohms per centimeter cube. Considerable differences were noted between individual values, but these were in most cases assignable to the presence of small stones and other inhomogeneities. Measurements were made in all holes to a depth of 4 feet. The mean resistivity values at the depths 0, 1, 2, 3, and 4 feet were 19,900, 12,400, 20,300, 34,000, and 68,000 ohms per centimeter cube respectively. When measurements in the same region were made, using electrodes spaced at equal intervals of about 6 feet on a straight line, the mean of 22 determinations was 14,200 ohms per centimeter cube and the individual values showed much less scattering.

Six series of observations along four different lines averaging about 180 feet in length were made with electrode separations varying regularly from 3 feet to 60 feet. The resulting data show lateral variations as well as variations with depth. The mean of 208 determinations is 21,100 ohms per centimeter cube. The two extremes were 8,000 and 31,000, including effects both of lateral and of vertical variation. Graphs of resistivities for various separations of electrodes indicate maxima when the separation of electrodes is 10 to 15 feet. After this the resistivity falls off gradually, reaching a nearly constant value of 16,000 at a separation of 40 feet. Thus it seems that for the region covered by these results the earth-resistivity increases

from the surface downwards until a certain depth is reached, after which it decreases to an approximately steady value. This may be simply a local characteristic. It is contrary to the usual belief, and if more extensive measurements show this feature to be generally true it should have important practical bearing in electrical engineering.

The system for recording earth-currents at the Watheroo Magnetic Observatory.¹ O. H. Gish. *J. Wash. Acad. Sci.*, vol. 14, 120 (March 4, 1924).

That natural electric currents flow in the Earth's crust at times of auroral displays is quite commonly known owing to their interference with telegraphic communication at such times. That similar though less intense currents exist at all times can be shown only by careful observations. The results published by Weinstein (1902) and by Bauer (1922) show more convincingly than any others that such currents may be observed with profit. Modern theories of terrestrial magnetic variations also imply the existence of general systems of electric currents in the Earth's crust, and especially do the recent developments of Chapman make promise of clarifying the problem and stimulating interest in further experimental as well as theoretical investigations of the subject. A complete description of earth-currents requires a knowledge of the distribution of (1) the earth-resistivity, and (2) the earth-current potential. A description of the methods employed by the Department of Terrestrial Magnetism for determining the latter at its observatory near Watheroo, Western Australia, constituted the body of this paper (see abstract given on p. 258 of the Director's annual report for 1923).

Preliminary analysis of some earth-current storms primarily observed on telegraph lines. O. H. Gish.

Eight series of observations made on the circuits of the American Telephone and Telegraph Company at the times of three different earth-current storms (June 17, 1915, March 9, 1916, and March 4, 1920), together with data obtained at the Ebro Observatory during the first two of these and data for other storms observed on experimental lines at Kaafjord, Norway (1902-03), and at Watheroo (December 10, 1923), were investigated. Ten vector diagrams constructed from these data show that the changes which occurred in the earth-currents during these storms took place largely along a line of fixed direction at each locality. If this feature is established by further investigation and the direction of principal change determined and charted for the telegraph system, it should be an aid to the management of "traffic" at the times of earth-current storms.

From the data observed at New York during the storm of June 17, 1915, it was possible to construct 21 curves which show roughly the character, at 2.5-minute intervals, of the equipotential lines of the electric field at the Earth's surface resulting from the earth-current storm. These give evidence of appreciable and varying curvature.

Some of the outstanding questions which earth-current storm data obtained on telegraph lines are well suited to solve are stated and some suggestions made for improving the observations.

Results of preliminary earth-current measurements at the Carnegie Institution's Magnetic Observatory near Watheroo, Western Australia. O. H. Gish. *Phys. Rev.*, vol. 23, 779 (June 1924).

The first continuous records of earth-currents in the southern hemisphere were obtained in October 1923 on the recently constructed experimental lines at the Watheroo Magnetic Observatory, Western Australia. The method of measurement employed there is described in the *Journal of Terrestrial Mag-*

¹ Presented before the Philosophical Society of Washington, November 3, 1923.

netism and Atmospheric Electricity, volume 28, pages 89–108, September 1923. The chief novel features are (1) the use of five earthed points instead of the usual three, (2) provision for comparing the relative efficacy of aerial and subterranean connecting lines, and (3) the use of a multiple-point recording potentiometer.

The preliminary results obtained in November and December 1923 seem to show that the method employed is very satisfactory and has some distinctive advantages. Both gradient components show a pronounced diurnal variation. The south-north, taken positive when directed northward, has a principal maximum at about 7 a. m., a principal minimum near noon, a secondary maximum at about 5 p. m., and a secondary minimum near midnight, which is in qualitative agreement with the data from Berlin and Ebro.

The east-west component, taken positive when directed westward, is, however, simpler in form, showing only a single period, with maximum at 9 or 10 p. m. and minimum near 11 a. m.

Atmospheric-electric observations during the total solar eclipse of September 10, 1923.¹ H. F. Johnston. *Terr. Mag.*, vol. 29, 13–22 (Mar. 1924); (abstract) *Sci. Abstr.*, vol. 27, 538 (June 25, 1924).

The Department of Terrestrial Magnetism made observations of potential gradient, positive conductivity, and negative conductivity at Point Loma, near San Diego, California, on September 10, 1923, as well as control observations on the four preceding and four following days. Improved bifilar electrometers, which gave dependable determinations of potential, were used. Potential gradient was observed both by eye-readings and by continuous photographic registration. Conductivity was observed simultaneously with two Gardien conductivity apparatuses. Meteorological conditions were very steady for the day of the eclipse; there was a total range of 2°·5 centigrade in temperature, 9 per cent in relative humidity, and 0.02 inch in barometric pressure.

During the 20 minutes following totality, the temperature decreased 0°·8 centigrade, and the relative humidity increased 3 per cent. The sky was completely overcast with fog which extended above 17,000 feet. Observational irregularities due to leak on account of increased humidity or alteration of instrumental constants caused by changes in temperature were smaller than the errors of observation. It was found that the potential gradient for about half an hour immediately following totality was about 15 per cent subnormal. The electrical conductivity of the air and the air-earth current-density increased about 10 per cent above normal during the 10-minute period following totality. These results are in close agreement with those observed by the Department of Terrestrial Magnetism at Lakin, Kansas, on June 8, 1918, and at Sobral, Brazil, on May 29, 1919. There was a greater increase in the negative conductivity than in the positive conductivity of the order of 15 per cent.

Reports of the Committee on Earth-Currents and Polar Lights.² S. J. Mauchly. *Bull. National Research Council*, vol. 7, 105–107 (January 1924).³

The first of these reports, which is printed in full in the Transactions of the American Geophysical Union, fourth annual meeting, April 1923 (reference as above), applies for the year ending March 1923. Two matters of interest covered by the report are the resumption early in 1922 of earth-current

¹ Presented before the Philosophical Society of Washington, December 15, 1923.

² Presented at the annual meetings of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923, and May 2, 1924. Members of Committee: J. H. Dellinger, N. H. Heck, A. J. Henry, A. G. McAdie, S. J. Mauchly, chairman, and W. E. Parker.

³ The report presented at the annual meeting in 1924 is not yet published.

registrations at the Ebro Observatory at Tortosa, Spain, after an interruption of several months, and the satisfactory progress on the first special system of earth-current lines to be installed in the southern hemisphere for the continuous registration of earth-currents at the Watheroo Magnetic Observatory in Western Australia. (For details with respect to this installation, see p. 258 of last year's report and pp. 300-301 of report for 1922.) Attention was directed to a record of the auroræ during November 1921 to June 1922 at Bowdoin Harbor, the winter quarters of the MacMillan Baffin Land Expedition of 1921 to 1922. Auroral observations are to be made by the observers on the *Maud* during Captain Amundsen's present Arctic Expedition. A plan was suggested by the committee whereby interested radio operators who are suitably stationed could probably obtain valuable data for determining the nature and magnitude of any possible interrelation between radio and auroral phenomena and at the same time supply indirect evidence concerning the ionization of the upper regions of the atmosphere during auroræ.

The second report covers the year ending in April 1924. The continuous registrations of earth-currents on the two special lines at the Watheroo Observatory were begun during the latter part of 1923; preliminary measurements, which have been reduced and summarized by Mr. O. H. Gish, show the method employed to be satisfactory and to have some distinctive advantages (see abstract, p. 180). Observations during times of earth-current storms are now being made by the American Telephone and Telegraph Company in the United States and by the Swedish Department of Telegraphs on the government-owned telegraph system of Sweden. A special system for continuous earth-current measurements has also been put into operation by Sweden at Alfsjö under the direction of Dr. David Stenquist.

A review was given of the new determinations of the wave-length of the green auroral line by Babcock and by Vegard and of the recent work of Vegard in which nitrogen crystals in a low-pressure atmosphere of nitrogen were bombarded with cathode rays with the apparent production of the green auroral line.

A brief summary was given of the results to date of the attempt to secure data regarding the effects of auroræ on radio transmission by cooperation between the *Bowdoin*, of Dr. Donald B. MacMillan's North Greenland Expedition of 1923 to 1924, and volunteer radio observers in various parts of North America. In general, the evidence to date suggests that the auroral effect is less than had been anticipated. Auroral observations at the Coast and Geodetic Survey Observatory at Sitka, Alaska, are now being regularly made, together with records of earth-current disturbances on cable lines entering at Sitka.

Observatory equipment for recording photographically the conductivity of the air.¹ S. J. Mauchly. Bull. National Research Council, vol. 7, 122, 123 (January 1924).

On the diurnal variation of the potential gradient of atmospheric electricity.¹ S. J. Mauchly. Bull. National Research Council, vol. 7, 131-135 (January 1924).

Improved apparatus for recording the electric potential of the air.² S. J. Mauchly. Phys. Rev., vol. 23, 302-303 (February 1924).

In the registration of the electric potential of the air frequent tests are made of the essential insulators of the recording system. However, it is seldom practicable to make such tests more than once daily, which obviously leaves one without much information regarding the state of the insulation

¹ Presented before the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 18, 1923.

² Presented at the meeting of the American Physical Society, Cincinnati, December 28, 1923.

during the remainder of the day. The apparatus described in this paper was designed to provide the maximum practical safeguard against defective insulation. Automatic insulation tests are made possible by the introduction of an auxiliary sulphur insulator as a section of the rod which supports the collector. This insulator is normally bridged across by a conductor, but once every three hours the contact is broken by a clock-controlled electro-magnet. This condition is maintained long enough to allow the registration, successively, of records indicating the approximate state of the essential insulators, the base-line, and the approximate state of the auxiliary insulator. With these data available, it is possible to reject all records which do not conform to an adopted standard of insulation, and thus to arrive at a better knowledge of the diurnal and annual variations of the Earth's electric field than can be obtained without such controls.

Atmospheric Electricity. S. J. Mauchly.

This was the subject of a radio talk broadcast on June 18, 1924, under the auspices of the Smithsonian Institution, from the station (WRC) of the Radio Corporation of America at Washington, D. C. It was a semi-popular exposition dealing with the nature of atmospheric-electric phenomena and the methods employed in their observation. The more important results and theories of atmospheric electricity were given and the chief outstanding problems indicated. Attention was called to the apparent correlation between atmospheric-electric conditions and those of radio communication.

An improved form of bifilar electrometer.¹ S. J. Mauchly and H. F. Johnston. *Phys. Rev.*, vol. 23 (February 1924).

This paper describes a modified form of the bifilar quartz-fiber electrometer devised by Wulf, in which various improvements are combined with the advantages inherent in the earlier construction. The chief advantage of the new form is its practical freedom from changes in calibration caused by variations in humidity. This feature is due to the elimination of the hard-rubber mounting customarily used for supporting the quartz tension-bow and the insulated "inner case," and the substitution of a base which is practically all metal and, therefore, not subject to humidity effects. Other new features provide more convenient accessibility to the fiber system for adjusting fiber tension and other sensitivity controls.

In its present form the bifilar electrometer is admirably adapted to work in electrostatics where it is desired to obtain, by means of a portable instrument, measurements of a precision and accuracy comparable to that obtainable on ordinary circuits by the use of a good voltmeter; it is also adapted to measurements on electrical systems requiring an instrument of low capacity, high insulation, and negligible period and self-inductance. Both the temperature coefficient and the humidity effects are practically negligible.

Principal magnetic storms recorded at the Huancayo Magnetic Observatory, January to March 1924. W. C. Parkinson. *Terr. Mag.*, vol. 29, 90 (June 1924).

This article lists seven principal magnetic storms recorded at the Huancayo Magnetic Observatory during the first quarter of the year 1924 and gives a brief account of the chief features of each.

Approximate astronomical locations around a base-station by use of wireless.² W. J. Peters. *Jour. Wash. Acad. Sci.*, vol. 14, 122 (March 4, 1924).

The method requires a prearranged program according to which the base-station broadcasts altitudes of selected stars, or of the sun, as actually meas-

¹ Presented before the meeting of the American Physical Society, Cincinnati, December 29, 1923.

² Presented before the Philosophical Society of Washington, November 17, 1923.

ured at the instants of distinctive signals sent out in groups for each star, or for the sun, in groups several hours apart. At the secondary station of which the geographic position is required, altitudes are measured simultaneously with the base-station. The differences of the simultaneous altitudes thus measured at the two stations may be plotted on any convenient scale with angles between them equal to the horizontal angles between the stars observed or between the positions of the sun in the various groups. The intersection of the perpendiculars erected at the ends of the plotted differences, or the Sumner lines, fixes the relative position of the base-station. If the object is merely to find the way to the base-station, the plotting of the differences may be done upon the ground without the use of drafting instruments by laying off the directions on any convenient scale towards the stars observed; the perpendiculars may then be struck off by any convenient means. No computations are required other than getting the differences of altitude, and observations may be repeated from time to time on the journey to the base-station.

In this method there are no data required from the ephemeris; calculations are reduced to the taking of means, which is optional, and to the final two subtractions; there are no entries to be made in navigational or logarithmic tables; nor are chronometer rates and corrections to be computed. Of course, the method has limitations such as imposed by atmospheric conditions and conditions of travel; it has also possibilities of application at sea, in the air, and on land.

Preliminary report on the atmospheric potential-gradient recorded at the Apia Observatory, Western Samoa, May 1922 to April 1924. A. Thomson.

This report gives preliminary summaries of the atmospheric potential-gradient data compiled from the continuous records obtained during the two years May 1922 to April 1924, at the atmospheric-electric land station of the observatory. Classifying days without negative potential, days with negative potential for less than 3 hours, and days with negative potential for more than 3 hours as 0, 1, and 2, respectively, the records obtained during the year May 1923 to April 1924 show 169 days of class 0, 156 days of class 1, and 41 days of class 2, while the total number of hours of negative potential-record was 367, distributed on 52.5 per cent of the days for a total of 4.2 per cent of the whole time. At times the high values of the negative potential occurring were sufficient to produce a spark discharge across a gap of 3 mm. The resulting diurnal variation in the potential gradient is nearly the same throughout the year with two maxima at about 8^h and 19^h, local mean time. The afternoon minimum, although pronounced, does not show so low values as the second minimum occurring between midnight and 4^h. These agree with the results of Dr. Angenheister (1914 to 1918) on the same site and confirm the opinion that the single maximum obtained in his reduction of the series from 1906 to 1909 was the result of the faulty insulation of the hard-rubber supports used for the collector. This is further borne out, since the published values for 1906 to 1909 are high for those months when the rainfall is light and are low during the rainy season.

The resulting mean value of the atmospheric potential-gradient for the total of 263 days of class 0 summarized for the period May 1922 to April 1924 is 109 volts per meter (the value for the second year of the series being 107 volts per meter). The two-year series indicate maximum values in May and in January, but it is doubtful if the available data are yet sufficient to draw definite conclusions.

Upper-air investigation. A. Thomson.

Sixty pilot balloons released at the Apia Observatory between June 1, 1923, and March 31, 1924, have been followed with a single theodolite to altitudes

exceeding 5 km. The flights were considered in two approximately equal groups, those made in the dry season, from June to October, when the trade-winds are blowing, and those made in the rainy season, from November to March, when the surface winds are irregular. The results from the two groups were very similar, with slightly higher velocities for the months from November to March. Throughout the year the wind velocities decreased from the ground to a height of 3 km. From 4 km. to 11.5 km. the velocity steadily increased to a maximum value of 13.0 meters per second (29.1 miles per hour). Although there were only a small number of balloons followed to a greater height than 11.5 km., on account of the maximum velocity being found at this altitude in both the rainy season and the dry season, this is very probably the height of the troposphere at Apia.

The wind velocities were resolved into north-south and east-west components. There was no pronounced north-south vector at any altitude, thus indicating the equatorial or polar drift to be small. The trade-wind component blowing with a velocity of 3.9 meters per second (8.8 miles per hour) at the surface is zero at a height of 2.5 km. Above this, westerly winds prevailed to the highest observed altitudes.

Meteorological report, 1922, Apia Observatory. A. Thomson. Annual Report Apia Observatory for 1922, 50-63 (1924).

Tables and statistics are given covering the meteorological observations made at Apia during 1922. Daily values at 9^h are given of the humidity, rainfall, wind, and visibility, and at 7^h, 14^h, and 21^h of temperature and pressure.

Submarine volcano in the Tonga Group. A. Thomson. Monthly Weath. Rev., vol. 51, 406 (August 1923).

A note on the appearance of an uncharted volcano in the Tonga Group.

The climate of Samoa. A. Thomson. Handbook on Samoa (1924).

The Apia Observatory. A. Thomson. Kalena, 20-21 (1924).

These two articles, of which the second is practically a summary of the first, discuss the climate of Samoa in the light of continuous records which reach back to 1890. The climate is of the tropical oceanic type, with the year sharply divided into a wet and a dry season by the southeast trade-winds, which blow from May to October. On account of the equalizing effect of the vast body of water which surrounds the islands, the daily range of temperature is small and the mean temperature of the coldest month is only 2°3 F. below the warmest month (December). The rainfall throughout the Samoan group is everywhere sufficient for vegetation, but varies widely from place to place. On the other hand, the humidity, although high, is remarkably uniform at all altitudes. During the wet season, from November to April, the winds are light and variable. Western Samoa has been free from cyclones since the disastrous visitation on March 16, 1889.

The Apia Observatory. A. Thomson. New Zealand report ending December 31, 1923, on the Mandate of Samoa to the League of Nations (1924).

This article describes the observatory's activities and gives a brief summary of the results in magnetism, meteorology, and seismology for the year ending December 31, 1923.

Ocean-drift investigation. A. Thomson.

An active campaign has been initiated by the Apia Observatory to obtain further knowledge in regard to the great ocean-currents of the South Pacific. Special forms were drawn up which are supplied gratis, together with other

accessories, to the officers of all ships traversing the South Pacific. These forms are placed in bottles, which are sealed and thrown overboard. A small reward is offered to the finder.

Apia Observatory, Samoa. A. Thomson and C. C. Farr. *Nature*, vol. 113, 355 (March 8, 1924).

This note gives a brief account of the activities and program of the observatory.

Records of earthquakes and of principal magnetic storms at the Watheroo Magnetic Observatory in 1923. G. R. Wait. *Terr. Mag.*, vol. 29, 48 (March 1924).

This article gives brief accounts and descriptions of details of earthquake records obtained on the magnetograms at the Watheroo Magnetic Observatory during March to December 1923, and of the principal magnetic storms recorded at that observatory during the year 1923.

Principal magnetic storms recorded at the Huancayo Magnetic Observatory, January to December 1923. W. F. Wallis and W. C. Parkinson. *Terr. Mag.*, vol. 29, 49 (March 1924).

This note gives the details of the three principal magnetic storms recorded on the magnetograms during March 24 to 25, September 26 to 28, and October 15 to 18, 1923, obtained at the Huancayo Magnetic Observatory. Brief descriptions of the chief features of the two storms of September and October are given.

TORTUGAS LABORATORY.¹

In accordance with special authorization of the Trustees of the Institution, investigations were continued at the Tortugas Laboratory during the summer of 1924. Dr. William H. Longley, of Goucher College, served, upon invitation, as administrative officer at the Laboratory during the season; and Mr. John W. Mills, chief engineer, remained in charge of all equipment and aided in collecting material for study and in securing supplies. The following investigators studied at the Laboratory during the season:

- Paul Bartsch. Continuation of breeding experiments with cerions. Cuba, May 27 to May 30; Tortugas, June 2 to June 15.
H. B. Bender. Collector. June 2 to August 25.
Caswell Grave. The organization and behavior of Tunicate larvæ. Tortugas, July 15 to August 8.
W. H. Longley. The habits of Tortugas fishes. Tortugas, June 2 to August 25.
S. Morgulis. The synthesis of uric acid in the southern lobster (*Panulirus argus*). June 17 to July 13.
H. S. Pratt. The distribution of certain Trematode parasites. Tortugas, July 12 to August 25.
A. A. Schaeffer. Continuation of studies on the structure, distribution, and reactions of marine amebas. Tortugas, June 17 to July 27.
W. L. Schmitt. Systematic-ecologic studies of the decapod crustacea. Tortugas, July 15 to August 25.
C. V. Taylor. Studies upon the organization of the echinoderm egg. Tortugas, June 17 to July 27.
W. R. Taylor. The marine algæ of Tortugas and their distribution. Tortugas, June 2 to July 27.
D. H. Tennent. Studies upon egg-organization, fertilization, and early development in echinoderms. Tortugas, June 17 to August 8.

In addition, mud dredged within the lagoon was forwarded by request to Dr. T. Wayland Vaughan, Director of the Scripps Institution, La Jolla, California, for study in connection with the problem of the formation of marine limestones; and to Professor L. B. Mendel, Yale University, algæ dredged at a depth of 40 fathoms to be used in his studies of nutrition in mice and rats.

REPORTS OF INVESTIGATORS.

Breeding Experiments with Cerions, by Paul Bartsch.

In order to add a spirally striated cerion element to the cerion colonies established at the Tortugas, Dr. Bartsch visited Cuba from May 27 to May 30 this year. Thanks to the good offices of Dr. Carlos de la Torre, of the University of Havana, he was able to secure a sufficient series of a strongly spirally striated new species of Cerion belonging to the *Cerion johnsoni* group at Mariel, where also a large number of *Cerion sculptum* likewise, though less strongly, spirally striated, were gathered. In addition to these, *Cerion mummia* from Marianao and *Cerion chrysalis* from Cabanas Fort and *Cerion tridentata* from Rincon de Guanabon were collected and planted at the Tortugas. The last is peculiar on account of the internal lamellation of the aperture and thus adds another element to our experiments.

¹ Situated at Tortugas, Florida.

On June 1 a visit was paid to the hybrid Cerion colony on Newfound Harbor Key. This was found to be in a flourishing condition and 100 specimens were taken to Washington for record and dissection.

June 2 to June 15 was spent at the Tortugas where various Cerion colonies had been established; these were studied and new ones added. All the colonies were found doing well, except that of *Cerion uva* from Curacoa, which is on the verge of extinction.

A number of F₂ Florida-grown specimens of *Cerion crassilabre* were gathered, which show no measurable differences from those of the check series of the F₁ Florida-grown generation, thus again confirming our finding with the other races of transplanted Cerions, that changed environmental factors have no appreciable influence upon the F₁ and F₂ generations of the transplanted material.

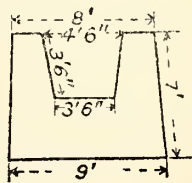
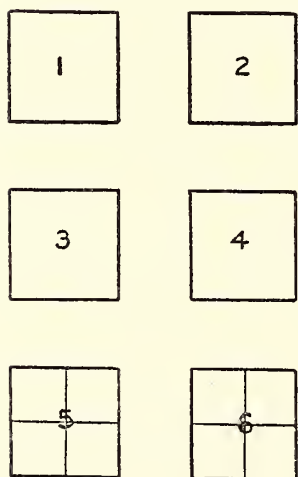
A large series of offsprings of the mixed colony of *Cerion casablancae* and *Cerion viaregis* (Colony I) were gathered and taken to Washington to be carefully studied for a possible cross.

New colonies of Cerions established this year at Tortugas are as follows: 500 *Cerion mummia* from the point at Miramar, Cuba; 500 *Cerion chrysalis* from near Cabanas Fort, Cuba; 500 *Cerion sculptum* from near the lighthouse at Mariel, Cuba; 125 *Cerion* n. sp., young specimens from a little east of the point at Mariel, Cuba; 500 *Cerion tridentata* from Rincon de Guanabon. These were planted on the west and north side of the parapet at Fort Jefferson on Garden Key, each duly marked with a stake and tag.

Our failure in the past to grow Cerions in cages at the Tortugas caused us to try isolating them on little islands. Mr. Mills inclosed four 6 by 6 feet areas with a concrete trench, a cross-section of the construction of which is shown in the accompanying diagram. Two additional areas of the same size were subdivided by a similar median septum which yielded four almost 3 by 3 feet islets. Each of the simple trenches require nine pails of water and the compound correspondingly more. Arrangements have been made with Mr. Charles Johnson, keeper of the Tortugas lighthouse, to keep these trenches filled with water. Evaporation at the Tortugas is great and it will be necessary to replenish the loss of water almost daily. For this purpose a pump has been installed in the middle of the battery of islands which will make this a comparatively easy daily task.

Each of the inclosed areas has been planted with a *Hymenocallis* plant and a few such grasses as are favored by Cerions, likewise a few added fragments of coconut petiole fibers; in other words, all things favored for attachment by Cerions. These islands are placed south of the laboratory and east of the men's quarters. They have been stocked with: 1, 25 *Cerion incanum* and 25 *Cerion* n. sp.; 2, 25 *Cerion incanum* and 25 *Cerion chrysalis*; 3, 25 *Cerion incanum* and 25 *Cerion mummia*; 4, 25 *Cerion incanum* and 25 *Cerion*

E



tridentata; 5 and 6 have in each compartment a two-thirds grown individual of *Cerion incanum* and *Cerion viaregis*.

On June 15, on our return to Key West, we visited Man Key and Boy Key. The Boy Key colony has in part survived the burning of last year, but that on Man Key has again been burned over and it is questionable if any living thing is left of it.

Thanks to the authorities of the U. S. Bureau of Fisheries we have been able to establish two colonies within the compound of the Fisheries station at Key West, where they will be safe from burnings. These we placed on the opposite extremities of the seaside leg of the grounds and consist of 500 specimens each of *Cerion viaregis* and *Cerion incanum*, and 500 each of *Cerion tridentatum* and *Cerion incanum*, respectively.

While at the Tortugas, Dr. Bartsch exposed 1,200 feet of moving-picture film with his undersea camera, photographing denizens of the coral reef. He took the precaution this year to place the camera upon a tripod, which has eliminated the sea-sickness producing effects secured during similar efforts last year when the camera was held freely in the hands while working in a rather rough sea. The negatives since developed are quite satisfactory.

As in previous years a full record of the birds seen from day to day was kept and added to the list secured in the past. This so far has yielded a large series of notes, not only on the avian population of the Florida Keys and the breeding habits of local forms, but much information on bird migration.

In addition to the work done at the various stations on the Florida Keys and Cuba, twenty of the hybrid Cerions from the Newfound Harbor colony have been dissected at the National Museum by Miss Mary E. Quick, under the direction of Dr. Bartsch. These show most remarkable changes in anatomic character. It is contemplated to make a greater number of dissections of these hybrid Cerions, in order to determine the range of changes produced by hybridization.

*Continuation of the Study of the Organization and Behavior of Tunicate larvæ,
by Caswell Grave.*

Dr. Caswell Grave spent a part of the summer at the Tortugas Laboratory studying the activities and structure of the free-swimming larvæ of certain species of ascidians, the systematic positions of which are intermediate between *Botryllus*, *Perophora*, and *Amaroucium*, the larvæ of which he has studied at the Marine Biological Laboratory at Woods Hole.

He found numerous species of ascidians abundantly represented and easily accessible, nine of which were reproducing during the period of his work at the Tortugas, July 15 to August 8. Of these he made a study of two; *Botryllus* sp? (probably *niger*) and *Ecteinascidia turbinata*. The larvæ of both were preserved for later study of their structure.

The observations made on the activities of the free-swimming larva of *Botryllus*, and the material preserved, should provide data by which to determine whether more than one species of this genus is represented by the several that have been described, mainly on the basis of wide differences in habitat, color, and color-pattern.

The species of *Ecteinascidia*, which was present in abundance in the Fort Jefferson moat, was found to be of unusual interest for, although specific differences could not be observed in the adult individuals, two well-defined

types of larvæ were liberated in the laboratory which were easily distinguished by differences in size, method of locomotion, reactions to light and gravity, duration of free-swimming period, and method of metamorphosis.

One species only of *Ecteinascidia* is known to occur in the West Indian region, *E. turbinata* (Herdman), and the specimens collected and preserved during the period of the present study by Dr. Grave have been provisionally identified by a specialist in the group, Dr. Willard G. Van Name, of the American Museum of Natural History, to be *E. turbinata*, although he states that they show variations from those he has previously examined from the Bahamas, Bermuda, and Florida.

It is to be regretted that the collection of ascidians made in 1907 by R. Hartmeyer at the Tortugas has not been made the subject for a full report, for a systematic study of the species of *Ecteinascidia* under consideration, by an expert in the group with numerous specimens available, might reveal specific differences.

Either two species of *Ecteinascidia*, so similar as not to be distinguished by any but an expert systematist, are living together at the Tortugas in the same restricted habitat and forming mixed colonies so intimately associated as to give every appearance of single colonies of a single species, or we have in this species one that exhibits a remarkable and unique dimorphism in its larval stage, each possibly adapted to serve a distinct purpose in the economy of the species. A study of the structural organization of these larvæ may throw additional light on the subject.

In addition to his study of ascidians, Dr. Grave made observations that indicate the presence of several species of animals that possibly exhibit a periodicity in spawning habits as definite as, and coincident with, that of the Palolo worm. On the date of the spawning of the Palolo worm, July 22, he noted at 10 o'clock in the forenoon that the water in the vicinity of Loggerhead Key was so laden with eggs that each bucketful contained literally many thousands, all in a late segmentation stage of development. At least eight kinds of eggs were present in each lot collected, distinguishable by differences in size and color. While cruising about the island during the day, the launch ran through long winrows of these eggs, several yards in width and several feet in depth.

The most conspicuous egg, because of its large size and pink color, was isolated in large numbers in dishes in order to identify the species if possible. Its type of segmentation showed it to be that of a Cœlenterate, and its odor when crushed between the fingers was that of a sea-fan. These eggs developed into very elongated planulæ, some of which were preserved for further study.

Prior to July 22, eggs had not been noted in the water that was brought in daily from the wharf, and the presumption is that none were present. On the 22d, and for two days thereafter, water could not be collected that did not contain them. After July 24 the eggs had disappeared from the surface and none were observed thereafter.

These observations indicate that several species, belonging to various Phyla, spawned simultaneously at or near sunrise on the morning of July 22, and suggest the availability of an abundance of material at the Tortugas for a most interesting and significant study of the problem of periodicity in the spawning habits of marine animals.

Observations upon Tortugas Fishes, by W. H. Longley.

During the 12 weeks between June 2 and August 25, 29 species of fishes were collected, which I had had no earlier opportunity to study. Half of these were secured in dredging operations undertaken primarily to satisfy the needs of other investigators, or in intensive shore collecting carried on by them. The group includes 9 identified species which have not hitherto been recorded from Tortugas. These are *Alutera punctata*, *Alphestes afer*, *Callionymus bairdi* (?), *Canthidermis sobaco*, *Lobotes surinamensis*, *Lycodontis ocellatus*, *Ogcocephalus radiatus*, *Spheroides pachygaster*, and *Synodus intermedius*. It also includes 9 or 10 other species not yet identified, all of which will probably be new to Tortugas, and some of which may be new to science. With additions required by these observations the Tortugas fish fauna is now known to include 275 species.

Living specimens of only 14 of the 29 species were available for study, but this material permitted the addition of *Alutera punctata*, *Alphestes afer*, *Cephalacanthus volitans*, and *Synodus intermedius* to the list of fishes whose coloration is readily changeable, and whose color changes tend to adapt them readily to new surroundings as they move from place to place. In addition, study of familiar species resulted in the observation of changeable coloration or of additional color phases in *Anisotremus surinamensis*, *Caranx crysos*, *C. ruber*, *C. latus*, *Cryptotomus beryllinus*, *Lactophrys triqueter*, *L. tricornis*, *Neomænis apodus*, *Scorpæna grandicornis*, *S. plumieri*, and *Synodus fætens*.

Little time was spent in submarine photography. I am indebted to Dr. Bartsch, however, for the privilege of testing with his apparatus the possibility of employing the motion-picture camera in such studies as I have been making, and believe it might be used effectively.

One point to which attention was particularly directed during the season is the detail with which the color pattern is worked out in a number of interesting cases.

In a species of *Callionymus*, probably *C. bairdi*, the first dorsal fin, supported by 4 spines, though narrow, is very conspicuous when elevated, equalling in height, as it does, one-third of the entire body-length. On the left side its web is yellow with minor markings of other colors, and on the right it is the same, except between the first two spines. On this portion of its surface, which alone is exposed when the fin is folded along the back in its position of rest, the identical combination of gray is found that mottles the dorsal surface, with which it blends perfectly, completely masking the gayer colors.

The outer faces of the oral breathing valves of the jew-fish, *Promicrops guttata*, are spotted like the adjacent external surface of the body. *Pterophryne gibba* goes farther, it would seem, in the direction of camouflaging the mouth cavity. It lives almost exclusively in floating Sargassum. Its color patently accords with, or repeats, that of its normal surroundings, to the extent that the color of fishes commonly does when the general character of their environment varies little from point to point. But in addition, when the great mouth that enables it to swallow other fishes almost as large as itself gapes, the tongue and floor of the pharynx to and including the fourth branchial arch may be seen to be marked with mottled brown and white as in the external pattern.

Callionymus and *Pterophryne* are perhaps unique among fishes in respect to the characters mentioned, but minor peculiarities in coloration, whose func-

tion appears to be the masking of eye movements, are very common. In a simple case the ball of the eye, in so far as it may be exposed in normal movements, is of one color. This is true of *Pomacanthus paru*, where, although the adjacent skin of the head is black, iris and eye-ball are yellow, and, when the body is still, little betrays the shifting glance except the moving pupil.

Petrometopon cruentatus, *Epinephelus adscensionis*, and *Alphestes afer*, to mention no others, illustrate a more complex relation. In these species it is not a simple color unrelated to that of adjacent parts of the head that appears upon the eye. Upon the contrary the color and pattern of adjacent parts appear upon the eye with such distribution that, though the pattern on head and eye are not continuous, rolling of the eye under normal conditions exposes no unpatterned surface that betrays it.

In the fishes last mentioned it is a pattern of comparatively small rounded spots that marks both head and eye, and no individual extra-ocular element is carried or appears to be carried across the gap where the skin dips into the orbit to invest the eye-ball closely. This most complex relation appears clearly, however, in at least some specimens of *Balistes vetula*. In this species radiating lines on the head center on the eye, and in the normal resting position of the eye appear to be continued directly upon it, because spots of the identical color abut directly upon their inner extremities. Even more striking is the fact that while the front of the eye is irregularly spotted, these larger spots related to the radiating lines are extended laterally upon the eye ball, with the result that, when the eye rolls, more and more of their length normally hidden is revealed, and the continuity of the ocular and extra ocular patterns well maintained upon the whole.

How complicated a thing the common matter of carrying a stripe from the head across the eye in such a way that its apparent continuity may not be interrupted by eye-movements is, may best be illustrated by reference to such a fish as *Chatodon ocellatus*, which shows a simple black bar of the width of the pupil passing through the eye from occiput to ventral margin of the gill-cover. Above and below the eye the pigment of this black bar lies in the skin. It crosses the fore part of the eye upon the iris, and by optical illusion incorporates with itself the black of the retina exposed through the pupil. Its apparent continuity under practically all normal conditions is assured by an extension of a band of black pigment of the appropriate width, above and below upon a portion of the sclerotic not exposed in the eye's normal resting position. The line functions as a unit, but is composed of at least three parts lying at four different levels in the tissues.

Two interesting cases of sexual dimorphism in color came to light during the season. The first is that of a small goby, sexually mature at 2 inches, and found in deep muddy-bottomed holes between Bird Key and Bird Key Reef. The second is the case of *Eupomacentrus analis*, doubtfully and erroneously suggested by me in Year Book No. 20 to be identical with *E. leucostictus*, where in addition I ascribed the young of *analis* to the last-named species.

Eupomacentrus analis may best be distinguished from *E. leucostictus* by the fact that in it the scales on the preopercle approach less closely to the posterior margin. It has no black spot on the dorsal surface of the caudal peduncle as *E. leucostictus* usually does. The dorsal ocellus is higher up upon its fin, and the dark dorsal color is not extended ventrally in vertical lines following the rows of scales. The distribution of the two species upon

the reef is different, and there are other differences unnecessary to mention here.

Confusion regarding the relation of these two forms to one another and to *E. fuscus* is sufficiently explained by the fact that all three species, and particularly *E. leucostictus* and *E. analis*, undergo striking changes in appearance with age, that *E. fuscus* and *E. analis*, the latter particularly, display as adults considerable ability to undergo temporary changes in coloration, and that the adult female *analis* may show decided resemblance to the *leucostictus* type. The colored plate of *E. leucostictus* in Evermann and Marsh's *Fishes of Porto Rico*, which is almost certainly a picture of *E. analis*, will serve, with my own mistake, as a permanent record of the difficulty of distinguishing these types.

The results of tests made to determine whether the gray snapper is capable of distinguishing between minnows marked respectively with a longitudinal dark stripe through the eye, or with two conspicuous transverse bars, were reported in the last Year Book. That the fish possesses the ability to make such discriminations seemed to be indicated then, but much additional work was plainly required before the rate at which it might be taught to avoid the one type while accepting the other would appear.

To the investigation of this point attention was directed for 26 days this summer. Daily 40 pairs of striped and banded minnows were fed in regular alternation to a selected colony until it was clear that the two sorts were being accepted with equal readiness. The banded fishes were then made distasteful by sewing in their mouths pieces of the tentacles of *Cassiopea*, and the experiment was continued 19 days longer without additional change in procedure. The departure from equality in the length of time elapsing before members of a particular pair were taken was slow, but during the last 5 of the 19 days the stinging bands were from day to day taken more slowly than the stingless stripes in about 65 per cent of the cases. On the 26th, and last, day of the experiment stripes and bands were offered as usual, except for the fact that neither sort was provided with stings. In spite of this fact, however, the discrimination against the bands was very noticeable, the banded member being taken more slowly than the striped in 32 of 44 pairs offered.

The results obtained then are quite consistent with those of the previous season and materially advance the analysis of the problem, though the rate of learning proved so much slower than previous experience had indicated it was likely to be, that progress in the research was not as rapid as had been anticipated.

*Further Experimental Studies on the Blood of the Crawfish, Panulirus argus,
by Sergius Morgulis.*

In an earlier investigation (Year Book 21, pp. 172-176) it was observed that wherever a solution of urea was injected intramuscularly into a crawfish a definite and unmistakable reaction for uric acid appeared in the blood, though before the injection the reaction was negative. In as much as the uric acid content of the blood in this animal is closely related to their state of nutrition, disappearing completely after they have been without food for one or two days, the rise of the uric acid curve in fasting individuals receiving an injection of urea is indeed very striking. In these earlier tests we employed Benedict's uric acid method which depends upon the direct development of

a blue color in blood filtrates treated with his special arseno-tungstic reagent. Fearing that perhaps some substance other than uric acid might be responsible for this color development (a consideration one must always bear in mind in tests involving color production), experiments were likewise performed in which the Morris-Macleod method of precipitation of the acid as a zinc compound was used to isolate it. Qualitative tests for its presence were then made, or quantitative determinations, where it was present in the precipitate in sufficient amounts for analysis. The precipitate was redissolved in accordance with the Morris-Macleod procedure, but the Benedict reagent was used for the development of the color. These experiments established definitely that the positive color reactions were actually due to the presence in the blood filtrates of uric acid, the results by the direct method of color production (Benedict's) and by the method of preliminary precipitation of the uric acid being practically the same.

The deproteinization of the blood samples was carried out by the Folin-Wu tungstic-acid method. The crawfish were generally bled from the telson, the blood being collected into a graduated cylinder containing a measured quantity of hot water. The hot water served a double purpose of diluting the blood and of preventing its coagulation. As a rule one volume of blood was diluted with three volumes of water. To this was then added 0.5 volume of a 10 per cent sodium-tungstate solution and, drop by drop, 0.5 volume of a $2/3$ N sulfuric acid. This proportion of reagents has been found sufficient to completely remove the proteins from the blood of the crawfish. The amount of water, on the other hand, has occasionally been varied in such a way as to obtain more concentrated blood filtrates. The quantity of filtrate used for each uric acid determination usually corresponded to 2 to 4 c. c. of the original blood.

The experimental procedure was very simple. A crawfish which had already been in the aquarium for one or two days was bled to get a preliminary blood sample, and immediately following this operation the desired substance, dissolved in 10 c. c. of sea-water, was injected into the muscles of the abdomen. The experiments with urea were carried out in three ways. In one series, the urea was introduced through a rubber catheter into the intestinal tract in quantities as large as 4 grams, the blood being taken just prior to and at definite intervals after the administration of the urea. The results of experiments carried out in this way were entirely negative, the uric acid content of the blood showing no variations following the enteral administration of urea. In the other experiments urea either alone or in combination with glucose was given by way of intramuscular injections. The results of these experiments are recorded below. It should be noted that in some experiments the color developed was not strong enough to permit accurate quantitative measurement. In such cases the presence or absence of the reaction was indicated by the conventional plus or minus sign, the relative intensity of the colors in a series of tests being shown by varying the number of (+) signs.

Summarizing briefly the results of experiments with urea here recorded it is to be noted that the administration of this substance, even in large quantities by way of the intestinal tract, produces no detectable effect on the blood uric acid content, but when given intramuscularly the uric acid content of the blood invariably shows a rise after an injection. It also appears that this rise is more definite and quantitatively greater when urea is injected in combina-

tion with glucose than it is with a similar amount of urea alone. This difference can not be attributed to the glucose, because injections of glucose have no effect upon the uric acid content of the blood. On the other hand, when very large doses of urea (3 grams) were injected there was a most striking increase in the blood uric acid (experiments 32, 33).

Injected intramuscularly 1 gram urea and 0.5 gram glucose.

No. of expt.	Preliminary.	Hours after the injection.							
		1	2	3	6	8	9	10	16
23....	(-)	(+?)	.....	.....	.....	.....	(++)	.....	.....
24....	(-)	.....	0.6 mg.	.....	.....	.....	.....	.....	(+)
25....	(0.6 mg.)*	.....	.....	1.3 mg.	.....	0.8 mg.	.....	.....	.....
26....	(+?)	.....	(0.3 mg.)	.....	.....	.....	.....	(0.2)	.....
27....	(0.2 mg.)	.....	.....	0.5 mg.	0.6 mg.	.....	.....	.....	.....

Injected intramuscularly.

No. of expt.	Urea Grams.	Preliminary.	Hours after the injection.						
			2½	3	4½	5	6	10	12
28....	1.0	(-)	(++)	.....	.....	.....	.....	.....	.....
29....	1.0	(+)	.....	(-)	(++)	.....	.....	.....	.....
30....	1.0	1.2 mg.	.....	(-)	.....	.....	(-)	.....	2.2 mg.
31....	1.0	(+)	(++)	.....	.....	.....	(+++)	.....	.....
32....	3.0	(-)	.....	1.3 mg.	.....	.....	4.5 mg.	.....	.....
33....	3.0	(-)	.....	.....	.....	1.6 mg.	.....	3.2 mg.	.....

* Quantities recorded in parentheses are only approximations.

In view of these observations it seemed desirable to test the effect of ammonium salts and of amino acids, the animal's reaction to which might throw light upon the appearance of uric acid in the blood following intramuscular administration of urea. It had been observed previously that ammonium sulfate, even in small doses, is not well tolerated by the crawfish. It was, however, possible to keep animals alive long enough to study the effect on the blood composition when the dose injected did not exceed 0.5 gram. The changes which this substance invariably produced in the composition of the blood were indicative of a strong diuretic effect, inasmuch as every component of the blood, which was quantitatively determined, was greatly diminished following such injections. Experiments with ammonium citrate gave practically the same results even when the reaction of the solution to be injected was adjusted almost to neutrality. In this case the animals, though they reacted to the injection most violently (convulsive movements), frequently survived for a few hours. But so far as the uric acid content of the blood is concerned, no alteration has been observed under these experimental conditions. The uric acid reaction remained invariably negative, even in those experiments where samples of blood were taken 9 hours after the injection.

The results obtained in experiments where ammonium lactate was used for the injection were more variable but also more suggestive. In amounts of

about 1 c. c. diluted with 10 c. c. sea-water, injections of ammonium lactate usually caused quick death. Only in one experiment did the crawfish survive the injection and several blood samples were taken at intervals in the course of 9 hours, but the uric acid reaction in the blood remained negative after the injection. When much smaller doses of ammonium lactate were injected (0.1 to 0.2 c. c.) a definite positive reaction was observed in some of the experiments, though this was never strong enough to permit quantitative estimation of the uric acid present in the blood sample. The record of two such experiments follows:

Ammonium lactate.	Prelimi- nary.	Hours after the injection.			
		2	5	8	22
c. c.					
0.1	(-)	(+++)	(++)	(+)	(-)
0.2	(-)	(+)	(+?)	(-)	(-)

It seems probable that the difference in results obtained from the use of large and small doses of ammonium lactate can be explained as being due to a different degree of diuresis which they occasion. The diuretic action of larger doses of the various ammonium compounds utilized in these experimental studies is very apparent when their effect is studied upon the various blood components. Thus, the very rapid diminution, and indeed the fall far below their original level, of all the non-protein components of the blood suggests definitely that a strong washing-out process occurs under the influence of these substances. This effect is shown well in the case of the blood sugar. This generally increases when anything is injected intramuscularly. A greater or less increase in the blood-sugar curve is associated even with an injection of pure sea-water. The condition, however, is completely reversed when an ammonium salt is injected in quantities sufficient to produce definite deleterious effects. Under these conditions the blood sugar, together with all other non-protein blood components, falls below the initial level and, furthermore, attains very quickly values much lower than those ever observed, even after several days of fasting. In view of this it does not seem unreasonable to assume that possibly the persistent negative reaction for uric acid, following the injection of the large doses, is really caused by the vigorous washing-out process and does not remove entirely the possibility that uric acid is entering the blood, even under those experimental conditions. This suggestion gains further corroboration from the observation that in the few experiments with small amounts of ammonium lactate which gave positive results, the diuretic washing-out process was likewise less prominent or indeed entirely absent. In these experiments with the small amounts injected the blood sugar actually increased, at any rate soon after the injection, as happens very generally after intramuscular administration, diminishing rapidly only in the later stages. If we regard, as we certainly must, the blood composition as being determined by a dynamic equilibrium between the inflow of metabolic products from the tissues and the outflow of these products from the organism by way of the excretory channels, then obviously the failure to note any changes in the uric acid content of the blood in crawfish receiving injections of

large amounts of various ammonium salts does not *per se* exclude the possibility that these compounds may become converted into uric acid, like urea. The failure to find this product may simply be due to its rapid disappearance from the circulation as soon as it is formed. On the contrary, when the washing-out process is less vigorous (and a study of the blood-sugar curve leads us to believe, that in the few experiments with the small doses of ammonium lactate, this was actually the case) we find a positive reaction for uric acid in the blood.

These considerations may likewise assist us in interpreting the difference in the results obtained with injections of urea alone or in conjunction with glucose. The urea through its well-known diuretic action would, therefore, tend to wash out uric acid as it enters the blood from the tissues. The added effect of glucose, by increasing the osmotic pressure, would tend to offset, at least to some extent, the diuretic process and thus would account for the fact that the results from a combined injection of urea and glucose are more definite than those obtained with injections of urea alone. On this view it also becomes clear that very large doses of urea, which must greatly raise the osmotic pressure within the tissues and thus effectively oppose its diuretic action, cause a large accumulation of uric acid in the blood. Experiments 32 and 33, where 3 grams of urea were injected, show how greatly the uric acid content of the blood actually increases under these conditions.

In conclusion, the results of experiments will be reported where glycine was injected intramuscularly. Unfortunately there were only a few performed with this substance. In one experiment a gram of glycine was injected into a crawfish whose blood before the injection gave an entirely negative uric acid test. At the end of $2\frac{1}{2}$ and 5 hours after the injection, the uric acid content of the blood has risen to 0.7 and 0.9 mgm. per 100 c. c. blood respectively. In two other experiments 0.6 gram of glycine were injected. In one experiment a good (++) uric acid reaction appeared 2 hours after the injection, which still persisted at the end of 5 hours, but disappeared completely after $7\frac{1}{2}$ hours. In another similar experiment the preliminary blood sample was not free from uric acid, but 2 hours after the injection this had increased 50 per cent, reached the original level after 5 hours, and decreased slowly afterwards.

The production of uric acid when urea is administered intramuscularly is very definite. The experiments also indicate that at any rate under certain conditions the injection of ammonium lactate and of glycine may be associated with a production of uric acid in the crawfish. There are three possibilities for accounting for the origin of the uric acid in the blood. It might be suggested that the extra uric acid is thrown into the circulating fluid from the tissues where it has been present as a reserve. We can at once dismiss such an explanation because, as a matter of fact, the reaction is best observed in animals which through fasting have already been made free from uric acid. Another possibility is that urea and the other substances used stimulate the metabolic activity of the cells, which results in a greater uric acid production. This view has been proposed by Lewis, Dunn, and Doisy, who studied the effect of various amino acids and of urea and ammonium salts on the production and elimination of uric acid. However, the results of their investigation are decidedly different from those reported in this paper. These authors found that the amino acids were the active agents in stimulating cellular

activity while urea and ammonium salts were entirely inactive in this respect, whereas we found urea the most potent source of the uric acid, while glycine and ammonium salts were less effective in increasing the blood uric acid. We finally have the third possibility of a synthesis of uric acid from urea as its precursor. It has already been suggested by students of purine metabolism that the organism may synthesize urea into purine bases, and the results of our experiments with the crawfish furnish a basis for the hypothesis of synthesis of urea into uric acid in arthropods. It is our intention to extend these studies.

*Preliminary Report of Certain Studies of the Trematodes of Tortugas,
by H. S. Pratt.*

It was my intention during my short stay on Tortugas to concentrate my attention on two or three matters of special interest, inasmuch as it would be unprofitable to make general collections of parasites in the 13 days at my disposal. One of these was a continuation of my study of the parasites of the 4 species of sea-turtles frequenting the Gulf of Mexico. These turtles are of cosmopolitan distribution; the parasites of 2 of the species have been studied by European investigators, who obtained their material in the Mediterranean Sea. A comparison of the parasites living in individuals of a cosmopolitan and widely ranging species of animals, which have been captured in widely separated localities, is of peculiar interest from the standpoint of the geographical distribution of animals. Unfortunately, no turtles were captured while I was on the island.

Another matter of interest was to learn more about a very peculiar trematode worm discovered by Professor Edwin Linton at Tortugas in 1907 in the chub (*Kyphosus sectatrix*), and named by him *Deontacylix ovalis*, the chief peculiarity of the worm being the total absence of suckers or other organs of attachment, which are so characteristic of trematodes. Professor Linton found only a few specimens of this worm in a single one of the 7 chubs examined, and was unable because of lack of material to give a complete description of its anatomy or to supply any information as to which of the organs of the fish the worm infests. His supposition that the worm was probably an intestinal parasite has, however, been noted by Professor Teodor Odhner of the University of Upsala, who has suggested that it is rather a blood parasite, living in the blood stream, basing his belief upon the absence of suckers and also on the similarity of its structure to that of *Sanguinicola*, found by Plehn in the European carp, and also of *Aporocotyle*, which he himself has described from the flounder, both of which are undoubted blood parasites.

I examined 10 chubs in my search for this worm and found a single specimen. This individual is 2 mm. long and a little less than 1 mm. wide, and was found inclosed in a large cyst several times the size of the worm, which was imbedded in the intestinal mesentery alongside the mesenteric vein. These facts indicate that the fish is the intermediate host of the worm, and also that the latter is not an intestinal parasite, at least of the chub. A description of its anatomy will be published later.

A third matter which interested me was the examination of the Gastropoda of the region for larval trematodes. About 15 species of common reef-snails were opened, including 40 individuals. Of these only a single individual contained trematode parasites. This snail was an *Astræa americana*; its liver con-

tained a large number of sporocysts and free cercariæ, which will be described later. The fact that so few of these snails contained larval trematodes indicates that snails do not act as intermediate hosts of trematodes in tropical waters as often as in temperate regions. Correlated with this fact may be the very thick shells which characterize these coral-reef snails, which would render them more immune to the attacks of predacious fishes than the thinner shells of the snails of the temperate regions.

Investigations on Marine Amebas, by A. A. Schaeffer.

OBSERVATIONS ON NEW SPECIES OF MARINE AMEBAS.

Three new species of marine amebas were discovered this season at Tortugas, one of which was a species of *Cochliopodium* found in large numbers in the large tidal pool in Sand Key. The other two species belong to the family Thecamœbidæ (to which the common *T. verrucosa* belongs) and are of especial interest because they possess the characteristic ectoplasmic ridges of this family, although they are very small, one being 10μ and the other 14μ long. This shows again that the general morphology of the amebas affords a proper basis for classification for small as well as large species. Since one of these two species possesses usually from 3 to 5 longitudinal ridges on the ectoplasm and the width of the ameba is only from 12μ to 14μ , the possibility would seem to exist that amebas of this family as small as 3μ or 4μ in length could exist and still show at least one characteristic ridge. Now since this size is approximately at the lower limit of free-living amebas, there would seem to be no limits imposed upon the appearance of recognizable general morphological differentiation in the Thecamœbidæ at least, and presumably not in the other families. It may be remarked that the existence of this condition is of the greatest importance in the study of amebas, since a natural classification would be impossible without general morphological differentiation.

OBSERVATIONS ON THE OCCURRENCE OF PREVIOUSLY DISCOVERED AMEBAS.

The following previously described amebas were observed in the various cultures which were set up: *Dactylosphærium acuum*, *Mayorella conipes* var. No. 3, *Thecamæba munda*, *T. rugosa*, *Vexillifera aurea*, *Trichamæba sphærarum*, *Rugipes vivax*, *Pontifex horridus*, *P. minimus*, *Flabellula mira*, *F. citata*, *Gibbodiscus gemma*. The reappearance of *Thecamæba munda* (discovered in 1921) was of interest. This ameba has the chromatin arranged in the form of symmetrical polar caps, a unique arrangement. Only four individuals were seen when discovered, offering therefore a narrow basis for generalization. This season a considerable number were found in material from Key West Harbor which conformed to type, except that in one individual one polar cap was twice the size of the other one. *Pontifex minimus* was found among blue-green algæ in the moat of the Fort and conformed to type except that they had fewer pseudopods and many of them lacked yellow bodies in the endoplasm.

The hole dug into East Key in July 1923 is still there and at low tide there is about 20 cm. of water in it at the deepest part. A thick felt of blue-green algæ covered most of the bottom. Three species of amebas were found in it: *Mayorella conipes* var. No. 3, *Flabellula mira*, and *Rugipes vivax*. Sand Key Hole contained vast numbers of *Mayorella conipes*, all apparently of the same variety; length, from 40μ to 75μ ; nucleus 3μ to 4μ in diameter, with nuclear membrane 5μ to 8μ in diameter; numerous crystals and excretion spheres,

but no vacuoles in the endoplasm; some of the nuclei with hollow chromatin masses; food, diatoms and blue-green algæ. Associated with these amebas were found considerable numbers of a new species of *Cochliopodium*, a small number of *Pontifex horridus*, a large number of very clear *Thecamæba rugosa*, and a few *Rugipes vivax*.

REACTIONS OF AMEBAS TO VARIOUS CONCENTRATIONS OF SEA-WATER.

The reactions of various species of amebas to different concentrations of sea-water have been used during the past several years as important aids in the identification and fixation of species. This season the rate of movement of several species was studied in various concentrations of sea-water with results of unexpected definiteness. It was found that the optimum concentration of sea-water is considerably below the normal in every case when measured by the rate of well-coordinated movement. This was found true of amebas belonging to three different families, and is therefore probably general for marine amebas as a group. But this relation between optimum and normal concentration is probably not confined to the amebas, for two species of *Stentor*, which are exclusively marine, are extremely sensitive to any slight increase in the normal concentration of sea-water, but tolerate readily dilutions to 50 per cent. The discovery of this relationship may therefore be of importance not only in the study of ameboid movement, but in other work as well. I am making arrangements therefore to continue a phase of this work during the coming winter on a common marine ameba which is readily cultured inland.

Observations on the Decapod Crustacea of Tortugas, by Waldo L. Schmitt.

A period of six weeks, July 15 to August 25, was spent at the Tortugas Laboratory, studying and collecting the decapod crustacea in preparation of a systematic-ecologic account of the species represented in the region.

In furtherance of this aim, as thorough a carcinological survey of the region was made as the time permitted. The content and extent of the local crustacean fauna, its distribution and ecologic relationships, as well as the abundance and availability of the different forms comprising that fauna for laboratory purposes were studied. Rather extensive collections were made and preserved for further study, and a fairly complete series of color notes was made with a view to the ready recognition of most of the species in the field, together with records of occurrence and some habit observations. A number of very interesting problems regarding habits, economy, variation, and coloration have been suggested by the summer's work to which further study could very profitably be devoted.

There is one general feature that seems worthy of note at this time, and that is the undoubted richness of the fauna as compared with that of other regions for which complete records have been kept. A preliminary review of the specimens secured this year at Tortugas gives not less than 125 species of decapods. Of these at least a fourth, and no doubt more, should prove readily obtainable for laboratory purposes.

Omitting for purpose of comparison, all probable occurrences, freshwater forms, and species not taken in less than 100 fathoms, and including all records since 1860, Hay and Shore in their account of the Beaufort, North Carolina, decapods are able to enumerate but 137. From Woods Hole, likewise, including records covering many years work, only 51 species are

known, while Dr. Mary J. Rathbun's 1905 list of crustacea has but 69 decapods occurring within the 100-fathom line for all of New England, to which should be added 4 others developed by the Woods Hole Biological Survey. Verrill in his several papers on Bermuda crustacea, taking into consideration all records, brings together only 120 valid species of decapods, and the Biological Survey of San Francisco Bay, 1912-1913, but 46 of the 70 species reported from the Bay and adjacent region.

On the other hand Miss Rathbun's and Dr. Benedict's reports on the crustacea of Porto Rico include nearly twice as many marine decapods from within the 100-fathom line as were taken this summer at Tortugas, 242 all told, a figure rather emphasizing the possibilities of the Tortugas fauna, than otherwise. More dredging in the deeper waters of the Tortugas region would easily increase the total number of species, and the possibilities of reef and shallow-water collecting are by no means exhausted. One dredge haul south of Loggerhead Key, in about 40 fathoms, yielded 12 species, and a second haul the same day, 5 more.

Other groups of crustacea, stomatopods, amphipods, and isopods, were not neglected, fair collections also being brought back with a view of having them worked up by specialists and students of the several groups.

Preliminary Report on the Development of Egg Fragments, by C. V. Taylor and D. H. Tennent.

The results obtained by Boveri during the investigations which formed the basis of his paper *Zwei Fehlerquellen bei Merogonieversuchen und die Entwicklungsfähigkeit merogonischer und partiell-merogonischer Seeigelbastarde*, published in 1918, a year after his death, showed that conclusions based on mass fragmentation of sea-urchin eggs were untrustworthy. For this reason and also for the reason that Delage's statement (1899) of his results following cutting are not sufficiently detailed to be satisfactory in a matter of final analysis, it seemed desirable to us to reinvestigate some of the problems of the organization of the egg that are involved. We first associated ourselves in this work at the Hopkins Marine Station, Pacific Grove, California, in January 1923, and continued our collaboration during the past summer at the Tortugas Laboratory.

Within recent years it has become increasingly evident that many experimental studies on living matter require apparatus of the utmost refinement and precise control. For this purpose the method of micromanipulation has come to rank as an invaluable aid. The use of very fine glass needles and pipettes which are manipulated in a moist chamber on the microscope by a three-way holder, makes biological experimentation under high magnification possible. A considerable body of literature has already been published by Barber, Chambers, Peterfi, Taylor, and others, on the method itself as well as on data resulting from its application. Their results have served to emphasize the fact that refinement of technique is as indispensable to progress in biology as it is in the physical sciences.

Improvements in apparatus for micromanipulation are now not infrequently being made and described. Barber, Chambers, and Peterfi have each designed and described micromanipulators that afford excellent control of micro-needles and micro-pipettes. The micromanipulator used in the experiments herein described is of new pattern, and is believed to present certain

distinct improvements over other models. Its ample mass affords necessary stability. The extensive contact surfaces of its sliding parts, its simplified design, and the excellent workmanship of its construction, make its manipulation easy and give precision to its adjustments. A detailed description of this new manipulator, funds for the construction of which were provided by a grant from the Research Board of the University of California, will appear in a forthcoming issue of the University of California Publications in Zoology.

The eggs used in our experiments were those of *Lytechinus* (*Toxopneustes*) *variegatus*. We were able to obtain them in abundance and they were remarkably well suited for our experimental studies. Necessity enabled us to give an unexpected touch of local color to our investigation in the substitution of fresh ink taken from the ink sac of octopus, for India ink, in the modification of Boveri's method which we used for distinguishing between the animal and vegetal poles of the egg and for ascertaining the relation of the position of the cleavage planes and the micromeres to the micropyle. The nucleus of the mature *Lytechinus* egg, like that of *Strongylocentrotus*, as discovered by Boveri, lies indifferently in the animal or vegetal half of the egg. Its variable position probably depends on the degree of viscosity of the cytoplasm in which it lies. Differences in viscosity between the eggs of different females and, within narrower limits, between eggs of the same individual, became strikingly evident upon dissecting the eggs with the micro-needle. Likewise, facts regarding strength and weakness of the egg membrane became evident during our work. Time did not permit us to enter upon the special study of the relation between the strength of the membrane and the viscosity of the cytoplasm.

Two sets of preliminary experiments were performed. The first showed that there was nothing in our operative technique that would cause the parthenogenetic development of the egg. 50 eggs were pricked with the tip of the micro-needle and transferred to sea-water. None of these eggs developed. The second set of experiments convinced us that neither the slight flattening of the egg during operation, nor puncturing, nor cutting, would in themselves prevent subsequent successful fertilization and development. 187 eggs were successively flattened by means of the surface film of hanging drops of sea-water and either pricked or an incision cut with the micro-needle. Following this treatment the eggs were transferred with a mouth pipette to a dish of fresh sea-water. In this they were inseminated from 5 to 10 minutes after operation. The dishes were then placed in a moist chamber of running sea-water beside a dish containing control eggs. Of the 187 eggs thus compressed and either punctured or cut, about 85 per cent developed to swimming larvæ. Approximately 90 per cent of the controls developed to the same stage. In their rate of development it was evident that the experimental eggs were somewhat slower during early cleavage than were the controls. The swimming larval stage was reached by both sets at the same time.

Throughout our major experiments we adhered rigidly to the following method of procedure. Eggs which were extruded through the gonopores of a horizontally transected female, or eggs which exuded freely from the cut surface of a thoroughly ripe ovary, were pipetted carefully to a glass dish containing about 600 c.c. of fresh sea-water. They were allowed to settle and were then washed with one change of sea-water. In from 5 to 10 minutes this stock began to serve as a supply for the work of from 1 to 2 hours, when

a new stock from freshly opened females was prepared. The number of eggs in a given culture never exceeded a few hundred, and formed a scattered, almost invisible layer on the bottom of the dish. From the stock a single egg was transferred, as wanted, to a small drop of sea-water on a scrupulously clean cover-slip. Water was drawn with a mouth pipette from the drop until its surface film compressed the egg slightly.

The cover-slip was then immediately inverted over the moist chamber on the stage of the microscope and the egg brought into focus just above the tip of the micro-needle. When both the egg and the needle tip were in focus the needle tip was gradually raised into the drop of water containing the egg. If necessary, the egg was then gently turned with the end of the needle, so that it could be transected in any desired plane. The structures used as the basis of orientation were the micropyle and the polar bodies, both of which usually lie close to the micropyle. The planes of section were either (1) "vertical," that is, parallel to the polar axis, or (2) "horizontal," that is, at right angles to the polar axis. As the nucleus is eccentric in position, a vertical section may be "polar," i. e. through the poles, and result in fragments of equal size—halves—one nucleated and one non-nucleated. Similarly, a horizontal section may be "equatorial" and the nucleus may lie in either the animal or the vegetal half.

The nucleated and non-nucleated fragments were then transferred by means of the mouth pipette, each to an embryological watch-glass, "salt cellar," containing 8 c.c. of fresh sea-water. When the fragments had rounded up well (from 5 to 20 minutes after cutting), 2 or 3 drops of a light suspension of sperms were added to each dish. Shortly after the appearance of the fertilization membrane, each fragment was transferred to another watch-glass of fresh sea-water. Thus isolated, each developing fragment was carefully followed throughout its succeeding stages. On a few occasions a pair of fragments was kept in the same watch-glass in order that both might be kept under observation continuously. The sea-water in the watch-glasses was changed usually once, sometimes twice, daily. When not under observation the watch-glasses were either covered, or kept in moist chambers, to prevent concentration of the sea-water by evaporation.

By this method many fragments, both nucleated and non-nucleated, of both vertical and horizontal sections, were reared to a fairly normal pluteus stage. The method of procedure adopted was founded on experience. We first attempted the study of the fragments in a hanging drop in a shallow moist chamber placed on the stage of the microscope. Fragments isolated in a small drop of water in this manner usually failed in their development before the second cleavage.

When the cutting was done slowly, with a needle that was not too sharp, in such a manner that the surface layers of the egg were brought together before the actual severing of connection between the two parts, the fragments rounded up well, and upon insemination formed well-separated membranes. On the other hand, when the cutting was done quickly, with an exceedingly sharp needle, the fragments remained somewhat flattened on one side, and the fertilization membrane formed only on the more convex surface.

The total number of pairs of species-activated, nucleated, and non-nucleated fragments studied was 122. Cleavage of both members of the pair followed in 56 instances. Cleavage of the nucleated fragment followed in

18 only, of the non-nucleated fragment in 10 only, and of neither nucleated nor non-nucleated fragments in 38 instances. Cleavage, therefore, followed insemination in 74 of 122 nucleated fragments, and in 66 non-nucleated fragments. In addition 20 non-nucleated fragments, not included in the pairs mentioned above, were inseminated. Cleavage followed in 16 of these.

The data here given include the results of all of the species inseminations of egg fragments that we studied during 6 weeks. We found, as time passed, that we acquired greater facility in handling our material and were able to eliminate various sources of failure. Our record for the last 4-day's work on 31 pairs of fragments being 18 instances of cleavage of both members of a pair, 5 of the nucleated fragment only, 3 of the non-nucleated fragment only, 3 of neither, and 2 in which the two fragments, kept side by side in the same watch-glass in order to facilitate comparison, fused—fusion taking place after an amphiaster had appeared in each fragment.

During two of these days, July 23 and 24, we devoted our efforts to a final check on the normality and viability of embryos derived from sectioned eggs. The record of 17 eggs sectioned, when completed on July 27, was as shown in the table:

	Nucleated fragments.	Non-nucleated fragments.
Cleavage.....	14	12
Blastulæ with mesenchyme.....	12	9
Gastrulæ.....	10	7
Plutei 72 hours old.....	7	4

Of these 11 normal 72-hour plutei, 6 came from 3 pairs, 4 of the 6 being derived from horizontal sections, and 2 from vertical sections; 1 of the remaining 5 plutei developed from a nucleated vertical section, 3 from nucleated horizontal sections, and 1 from a non-nucleated vertical section.

We gave the last two days of our work together, July 25 and 26, to a final check on comparative cleavage. 14 eggs were sectioned. As noted above, the halves of 2 of these eggs fused during cleavage. From the remaining 24 fragments we had 8 pairs of nucleated and non-nucleated fragments, both members of which underwent satisfactory cleavage; 1 pair in which only the nucleated fragment cleaved, 1 in which only the non-nucleated cleaved, and 3 pairs in which neither the nucleated nor the non-nucleated fragment cleaved.

Delage (1899) inseminated fragments which he had obtained by cutting the egg into two parts, and obtained cleavage in 6 pairs. He states that cleavage occurred as in the normal egg, yet it is not clear that he made use of the one available landmark which would establish his conclusion beyond question. Such a landmark is afforded by the micromeres which are cut off from the vegetative pole in the normally fertilized egg at the fourth division, this unequal division of the 4 cells of the vegetative hemisphere in the *Lytechinus* egg usually being slightly in advance of the equal division of the 4 cells of the animal half of the egg. The result is a 12-cell stage of brief duration. These micromeres, after further division, become embedded in the posterior wall of the blastula and give rise to the primary mesenchyme, some of the cells of which secrete the larval skeleton.

From many pairs of both horizontal and vertical sections we obtained blastulæ with mesenchyme, normal gastrulæ with triradiate skeletal spicules, and plutei, which, except for size, could not be distinguished from those developing from normally developing entire eggs. But our answer to the question, as to whether the cleavage of both fragments was identical and as in the entire egg, must be in the negative.

In every pair in which our observations were satisfactory to us, the cleavage of one of the fragments followed the pattern of the normal egg, while in the other the division which should have given rise to the micromeres was an equal division of the cells of the vegetative half, or lower half, of the fragment, this division occurring shortly after the equal division of the 4 cells of the animal half of the fragment.

Our observations are conclusive also in their demonstration that a complete segregation of mesenchyme-forming material has not taken place before fertilization; that this material is not completely localized after the polar bodies have been extruded and before fertilization. In blastulæ derived from both horizontal and vertical sections, mesenchyme cells passed into the blastocoel from the posterior wall of the blastula and secreted skeletal spicules.

Our observations are also important in that they show that the original polarity of the egg does not necessarily persist in the fragment. With but one exception the first two planes of cleavage were at right angles to the plane of section, and the micromeres, when formed, appeared at the end of one of the intersections of these two planes. With one exception the long axis of the first cleavage spindle was parallel to the major axis of the fragment. In the exception mentioned the first plane of cleavage was parallel to the plane of section.

The results of our work with fragments of *Lytechinus* eggs inseminated with *Tripneustes* sperms were unsatisfactory. From 49 pairs of nucleated and non-nucleated *Lytechinus* egg fragments inseminated with *Tripneustes* sperms we obtained cleavage in 18 nucleated and in 15 non-nucleated fragments. Of these 33 out of a theoretically possible 98 cleaving fragments, 18 were given by 9 pairs. From 2 of the nucleated fragments we obtained blastulæ with mesenchyme, one of which went on to the gastrula stage. From 1 of the non-nucleated fragments we obtained a blastula without mesenchyme. We do not regard these results as conclusive in any respect, as the *Tripneustes* material was not in good breeding condition at the time that we were able to turn to this phase of our investigation.

We attempted one additional cross-activation, that of nucleated and non-nucleated fragments of *Lytechinus* eggs with *Echinometra* sperms. The inseminated fragments formed membranes, but did not divide.

Our findings are based on a study of more than 400 eggs, each one of which was isolated, and more than 200 of which were cut into fragments and the fragments followed during the first 3 days of their development.

After this work was brought to a conclusion D. H. Tennent spent two weeks in a continuation of his study of the relation between the permeability of the egg and specificity of fertilization. He found that the *Lytechinus* egg could be brought to a condition in which it was more readily activated by foreign sperm than by sperm of its own species.

It is also a matter of interest that two species of sea-urchins of the Tortugas region, *Echinometra lucunter* and *Brissus brissus*, were found to be mature

and entering their breeding season about August 1. Studies on both of these forms, upon which further report will be made, were begun. The egg of *Brisus*, in its cleavage, is unusual in that the 4 cells of the vegetative hemisphere divide to 8 before the formation of micromeres. Having divided to 8 the cells line up in a double row and at the next division each cuts off a micromere. There is no stage at which only 4 micromeres are present.

Report on the Marine Algæ of the Dry Tortugas, by Wm. Randolph Taylor.

The flora of the Dry Tortugas does not appear to the casual observer to be of even moderate richness, or to afford many plants that would be suitable for experimental purposes. A detailed survey of the flowering plants only serves to confirm this impression, for the number of species of these is small; however, the marine algæ prove to be abundant in the variety of species and also in the number of individuals of certain important types. During the months of June and July an attempt was made to prepare as complete a list of the species present at that season as possible, to secure data regarding vegetative and fruiting conditions, and a start was made on a very detailed study of the distribution of the more significant species, especially on Garden Key and Shoal.

The only previous list of Tortugas algæ available is that by Bowman¹ listing 29 species, although other persons have collected algæ on these islands and a very few specimens are preserved in the Phycotheca Boreali-Americana. Approximately 230 species and major varieties have been named by the present investigator from his collections, with indications that this number will be considerably exceeded when the study of the material in hand is completed. This number, present during but one brief portion of the year, would indicate a rather rich flora. The flora is characteristically tropical, with a notable dominance of Chlorophyceæ in shallow water and of Phæophyceæ at moderate depths, but without, so far as could be determined, the expected zone of Rhodophyceæ in deep water. As a result of this peculiarity the list of Rhodophyceæ only slightly exceeds that of Chlorophyceæ, instead of being over twice as great, as Børgesen found for the Danish West Indies (the Virgin Islands).

In quiet, shallow water the abundant forms were species of *Halimeda*, *Caulerpa*, and *Valonia*, and some members of the Cladophoraceæ. All the species of *Halimeda* of shallow water were in luxuriant vegetative condition, but only one, *H. scabra*, appeared to be bearing sporangia. The three *Caulerpas*, *C. racemosa*, *C. sertularioides*, and *C. cupressoides*, were in almost equal abundance. *Valonia macrophysa* was found in many situations, but on the wall in the moat of Fort Jefferson on Garden Key it developed in exceedingly great quantities, forming thick cakes, several decimeters in breadth over loose bricks, over sponges, or on projections of the wall itself. *Valonia ventricosa*, a larger species not forming cakes by the close associations of the cells, was common on the reef and frequent in a wide variety of other habitats. With the three genera of Chlorophyceæ mentioned there were a few Rhodophyceæ in abundance, notably *Acanthophora spicifera*, two *Laurencias*, and an *Amphiroa*. In water about 3 fathoms deep the vegetation, largely on broken corals, was dominated by Phæophyceæ of the genus *Dic-*

¹ H. H. M. Bowman, *Botanical Ecology of the Dry Tortugas*, Papers from the Department of Marine Biology, Carnegie Inst. Wash., vol. 12, No. 5, 1-138, pl. 1-6 (1918).

tyota. These grew in clean, luxuriant beds, generally in asexual, more scantily in sexual, reproduction. Some areas were covered with *Sargassum* or *Padina* instead of *Dictyota*, and one large area showed a dense growth of *Haliseris*. These also showed much more frequent asexual than sexual reproduction. Species of *Lithophyllum* were frequent at this depth, as also *Dasycladus clavæformis* and *Dictosphaeria favulosa*.

Dredging was undertaken, both with a launch to 5 fathoms and with the *Anton Dohrn* to 100 fathoms. The first was the more extensively practiced, and although the greatest part of the material secured was also obtainable near the surface, some new types appeared, such as *Chrysomenia* and *Chamaedoris*; and valuable data were obtained regarding the area range of the more abundant species on Loggerhead and White Shoals. With the *Anton Dohrn* the most important dredging was executed as a series of hauls out the Southwest Channel from Loggerhead Key to deep water at 100 fathoms. The most notable feature of this series was the depth to which the green algæ penetrated. Below the *Dictyota* level (about 5 fathoms) the types shifted so that at from 30 to about 60 fathoms the dominant types were *Caulerpa prolifera* and the splendid *C. ashmeadii*, associated with two species of *Halophila*, a marine phanerogam of great interest. The only frequent Rhodophycean present at these depths was *Halymenia floresia*, and it was far less abundant and descended to a lesser depth than these Caulerpas. From 75 to 100 fathoms the bottom was of soft ooze, not suitable as a substratum for the larger algæ, and barren, which feature may be the explanation for the apparent absence of the deep-water Rhodophyceæ, rather than conditions of illumination.

ARCHÆOLOGY.

Morley, Sylvanus G., Santa Fe., New Mexico. *Associate in Middle American Archæological Research.* (For previous reports see Year Books Nos. 13-22.)

Three separate expeditions were maintained in the field during the first six months of 1924, as follows: Dr. Morley, Messrs. Morris, Kilmartin, and Amsden in Yucatan, Mexico; Mr. Blom and Mr. Ricketson in Peten, Guatemala; and Mr. Ricketson in British Honduras.

The several activities in Middle American Archæological Research for the current year may be described under four main headings as follows:

1. The lectures and conferences of Dr. Manuel Gamio, Director of Anthropology of the Mexican Government in the Administration Building at Washington in April.

2. The Chichen Itzá Project under Dr. Morley, Messrs. Morris, Kilmartin and Amsden, being the first season's work at this site.

3. The Uaxactun Project under Mr. Blom, being the eighth season's work in the Peten region, and the first season of intensive work at this site.

4. The excavations at Baking Pot, British Honduras, under Mr. Ricketson, the first season's work at this site.

Dr. Morley left Washington for Guatemala on February 5 to confer with governmental officials of that country with regard to archæological investigations at the sites of Uaxactun and Tayasal in Peten.

Before leaving Guatemala, Dr. Morley delivered an illustrated lecture before the Geographical and Historical Society at the *Palacio Centenario*, covering the Institution's recent archæological work in that country and in Mexico.

During the fall of 1923 a formal invitation had been extended by the President of the Institution to Dr. Manuel Gamio, Director of Anthropology of the Mexican Government, to deliver two lectures in Washington in the spring of 1924, upon the results of recent archæological work in Mexico under the Direction of Anthropology.

Dr. Gamio accepted this invitation, and these lectures were delivered at the Administration Building in Washington on the evenings of April 16 and 17. An exhibition of native Mexican arts and crafts, as revived by Dr. Gamio at San Juan Teotihuacan, was held in connection with his lectures, and a remarkable collection of paintings, pottery, tiles, textiles, basketry, and native jewelry was shown.

The lectures were followed by two archæological conferences: one devoted to a discussion of the Chichen Itzá Project and general problems of archæological research in Mexico, and the other more specifically to Dr. Gamio's own work in Mexico and his proposed classification of the several cultural horizons represented there. These conferences were attended by twenty-five representatives of the following institutions and organizations: American Museum of Natural History, New York; Archæological Institute of America, Washington; Bureau of American Ethnology, Washington; Carnegie Institution of Washington; Direction of Anthropology, Mexico; Museum of the American Indian, Heye Foundation, New York; National Geographic Society, Washington; Phillips Academy, Andover; Peabody Museum of American Archæology and Ethnology, Harvard University, Cambridge; University of Arizona, Tuscon; and the United States National Museum, Washington.

Dr. Gamio's lectures and the material he exhibited convincingly set forth the importance of the archæological and sociological work now being carried on by the Mexican Government under his direction, and the conferences brought out a number of points relative to the conduct of archæological investigations in Mexico, and served to clarify several issues under discussion.

On May 12 Dr. Morley and Messrs. Morris and Amsden left New Orleans for Yucatan to start work at Chichen Itzá, Mr. J. O. Kilmartin, of the United States Geological Survey, having proceeded thither six months earlier (November 1923) to commence the survey and basemap of the site. See p. 213 for Mr. Kilmartin's report.

The work at Chichen Itzá in 1924 falls under two headings: (1) the erection of quarters for the staff and laborers, and the repair of the buildings leased from Mr. E. H. Thompson, the owner of the Hacienda of Chichen upon which the ruins are located; and (2) the excavations proper under Mr. Morris, whose report will be found on p. 211.

The property which has been leased by the Institution consists of the hacienda-house and its out-buildings, and a hundred acres of adjoining woodlands for the location of the necessary corn-fields and lime-kilns, and as a source of supply for building-stone, timber, and fire-wood.

It was impossible to undertake all of the necessary repair-work on this property during the current field season, but new roofs were added to four buildings; one of the rooms was floored with cement for use as a store-house; and doors were fitted in several places where they were missing. A new 2-room stone house with thatched roof was built for Mr. Morris, and the construction of quarters for the laborers was commenced along the south side of the principal square, which is to be known as the Park Chichen. It is estimated that at least 20 of these thatched dwellings will be necessary to shelter the required number of laborers.

Excavations closed at Chichen Itzá on July 5, and Dr. Morley and Mr. Ricketson returned to the United States by way of New Orleans on July 17, the remaining members of the staff proceeding thither by way of Vera Cruz and Mexico City on July 16.

Before leaving Yucatan Dr. Morley visited the Island of Jaina, off the north-west coast, to examine a newly-reported hieroglyphic inscription. This trip was undertaken through information received from Mr. W. R. Sheetz of Merida, who, together with Mr. Ricketson, accompanied Dr. Morley. The site is composed of half a dozen mounds, the easternmost of which is the second largest, being perhaps 30 feet in height. Fragments of two stelæ were found at its northeastern corner, carved with representations of rulers and deities and columns of hieroglyphics; and one of these (Stela 1) proved to be of the very highest importance, no less, indeed, than the fourth Initial Series yet to be found in the entire New Empire region, i. e., the Peninsula of Yucatan.

The front of this stela is sculptured with 9 human or divine figures, 4 seated across the top; 3, including the principal figure, standing in the middle; and 2 incomplete figures at the bottom. The sides and back are inscribed with hieroglyphs.

The inscription begins on the left side with an Initial Series introducing glyph, but most unfortunately in view of the importance of the text, the rest of the Initial Series, save only for a part of the katun-sign, is destroyed. The

day-sign, Supplementary Series, and month-sign which are presented on the right side are, however, almost perfectly preserved. The day-sign is either 12 Ahau or 13 Ahau, the former being the preferable reading; the month-sign is surely 8 Ceh.

Possible Initial Series values corresponding to these two terminal dates follow, although this monument may be of much earlier date than either:

11.18. 9.0.0 12 Ahau 8 Ceh, approximately 1329 A. D.

12. 5.15.0.0 13 Ahau 8 Ceh, approximately 1473 A. D.

In spite of the fact that only four Initial Series have yet been reported from the New Empire region, their distribution fairly well covers the Peninsula of Yucatan from east to west: (1) at Tulum on the eastern coast, (2) at Chichen Itzá in the northeastern quarter, (3) at Holactun in the northwestern quarter; and (4) at Jaina on the western coast. The particular value of this discovery lies in the fact that Initial Series stelæ are so exceedingly rare from the New Empire that the few known constitute historical landmarks of first importance.

Dr. Lothrop's report on the ruins of Tulum and the east coast of Yucatan (Pub. No. 335) was issued early in the spring. It contains 179 pages of text, 27 plates, of which 5 are in colors, and 182 figures.

Report of Mr. E. H. Morris on the Excavations at Chichen Itzá, Mexico.

On May 27, after one week's preliminary work, consisting of cutting new growth and burning the vast mass of timber felled in 1923, excavations were begun in the Court of the Thousand Columns at Chichen Itzá. The first point attacked was the natural entrance to the Column Group walking westward from the Castillo—a passageway through the building which flanks the western side of its main plaza. The building, which it transects, faced the west and consisted of a thick back wall, paralleled by 4 rows of round columns, the fallen drums of which were scattered over the area excavated. The passage itself was about 6 feet wide. It had been roofed with a typical Maya vault where it passed through the back wall, but had not been covered thence eastward.

Leading through the terrace, which supported the building along the north side of the main plaza, was a partially choked tunnel, only the extreme ends of which had fallen. This was the next feature excavated. It proved to be 66 feet long, 4 feet 9 inches wide at the bottom and 6 feet 5 inches from floor to capstone. The exposed faces of the terminal stones of the arch, both at the north and the south ends of the tunnel, had been elaborately sculptured, the motifs being jaguars and macaws.

The principal excavations of the season were centered upon the extreme northeast corner of the Column Group. The structure cleared there has been designated the Northeast Colonnade. It is an edifice 100 feet in length by 49 feet in width, facing south. The east, north, west, and the ends of the south boundaries were solid walls, but the remainder of the support of the superstructure was a series of columns, rectangular in cross-section. These are distributed in 5 rows from east to west, the northern 4 being 10 columns in length; the south, which is in reality the interrupted south wall, having only 8. These 48 columns vary little from 2 feet 4 inches from north to south and 2 feet in the opposite direction, and are separated by an average distance of 7 feet 2 inches. Their original height was practically 8 feet above floor-level.

The columns being rectangular, there was no necessity for capitals. Only the fifth and sixth columns of the 2 back tiers were sculptured. Graven into each face is the figure of a warrior in full regalia. Inclosing the 2 sculptured columns of the northernmost tier is an altar or throne extending thence to the rear wall of the building; it is 13 feet 3 inches east and west, 7 feet 3 inches north and south, by 3 feet high. The walls consist of a battered lower zone surmounted by a vertical cornice. Both of these elements were elaborately sculptured, the former with figures of warriors, the latter with intertwined serpents, from the mouths of which issue other warriors.

Bordering the east, north, and west walls is a broad bench, upon the rear edge of which is a row of stone slabs, their tops leaning against the walls, thus providing a sloping surface with an angle which would have afforded a convenient back rest for any one reclining upon the bench.

The arches of the building run parallel to the longer dimension, that is, east and west. These had rested upon pairs of hewn timbers which spanned the space from wall to column, or from column to column as the case might be. At the western end, where preservation was best, the proportions of the beams and every detail of arch construction was recovered. It was possible to ascertain that 106 beams had been used in the roof construction.

The hard, polished lime floor and the entire interior of the building had been painted, a rich deep red being the dominant tone. The bounding walls had been embellished with designs, composed, in the one place where the elements could be distinguished, of serpents and feathers done in yellow, blue, green, and red.

There was ample evidence of secondary construction. A rectangular room had been cut out of the northeast corner of the great hall by walling in the spaces between columns, and extending from the altar westward all intervals between the columns of the second tier from the north had been filled with dry-laid walls, probably for the purpose of holding up timbers which had begun to fall. Reused sculptured stones were plentiful in the secondary masonry, many in the northeast room evidently having come from the front façade, and several in the dry-laid wall having been torn out of the face of the altar.

The north side of the building, which rests upon a high embankment heaped up upon the sloping margin of a dead cenote, had begun to fall previous to abandonment. In an effort to strengthen the first column in the back row westward of the altar, a wedge of masonry had been built between the column and the rear wall. Forming the bulk of this were five atlantean figures, and a sixth was found in one of the intercolumnar secondary walls.

The principal units of the façade were: a battered basal zone, a vertical medial one, and a sculptured upper zone. At the west end of the south wall, owing to the fact that this part had been buried by the hearting of a stairway built subsequently against it to give access to a higher temple to the westward, the entire sculptured zone, though riven by settling and the roots of trees, was in place, thus revealing the nature and arrangement of some of the motifs. The lower cornice was composed of 3 members, of which the central band consisted of intertwined serpents with disks between the coils. At the western terminus the grotesque head of one of the serpents stood out in high relief, and beside it was a block, graven to represent the rattles of the tail of the serpent which extended in the opposite direction. Filling the vertical expanse above the serpent's head were two grotesque masks, one above the

other. Surmounting these was an upper cornice, a repetition of the lower one, except that the stones of its upper member were elongated, their tips forming the edge of the roof. Eastward from the mask panel, and separated from it by a plain band, was a vertical panel consisting of 3 disks or shields in relief. Masks and shield panels, alternating with grotesque human figures, continued thence to the southeast corner of the building where the arrangement was the same as previously described at the western end, except that the line bisecting the 90° angle formed by the corner would have been the medial line both of serpent's heads and masks. The western end of this façade was taken down and reset in cement, and the lower cornice replaced from fallen elements at the eastern end. The series of terraces leading from the north side of the structure down to the floor of the adjacent dead cenote will be cleared of débris and repaired next year.

The western terminus of the Northeast Colonnade abuts a much higher mound, on the south end of which there had been a small 1-roomed structure of which only the basal courses remained. The platform on which it stood was composed of rough stones, filling and heaped up against and around an earlier edifice extending at right angles to the Northeast Colonnade. Whether it was preexistent or contemporaneous has not as yet been determined. The southern end of this partly buried temple was excavated. Being the portion which was not filled up to form a base for the elevated one-roomed temple, and therefore available for subsequent use, it had been remodeled to form an individual structure, facing east, of essentially the same form as the Northeast Colonnade. The columns here are round, but surmounted by rectangular capitals. There are two doorways and one row of columns between them and the rear wall. A wide bench flanks the south and west walls. Extending forward from this, to, and somewhat beyond the central pair of columns, is a platform analogous to the one in the Northeast Colonnade. Throughout the building is of relatively poor construction. Extending into the mound at the northern limit of excavations, a portion of the sculptured façade is in place, revealing a large disk or shield as one of its elements.

The two buildings cleared seem to confirm the type of the most prevalent form of column-supported structure at Chichen Itzá, the features of which are a rectangular ground-plan with arches paralleling the longer dimension, a bench contiguous to the end and back walls, and an altar or throne at the center in the rear.

As might be expected in this class of excavation, the minor objects recovered were few; a fair quantity of potsherds, two nearly complete vessels, a few shell beads, a jade celt, and several flaked blades of obsidian.

With the completion of the replacement of the façade at the southwest corner of the Northeast Colonnade, the field work for 1924 was brought to a close on July 12.

Report of Mr. J. O. Kilmartin on the Survey and Base-Map at Chichen Itzá, Mexico.

In accordance with arrangements made by the Carnegie Institution of Washington and the United States Geological Survey, I proceeded from Washington on November 21 and sailed from New York on November 24 to Yucatan, Mexico, to undertake surveys of various natures for the Carnegie Institution at the ruins of Chichen Itzá, arriving at the port of Progreso on November 30 and at Merida a few hours later.

After presenting my credentials and letters of introduction to the governor of Yucatan, the late Don Felipe Carrillo, and to Don Felipe Canton, president of the Archæological Society of Yucatan, both of whom assisted greatly in facilitating my arrangements for supplies and transportation to Chichen Itzá, I proceeded to that place on December 5 and began immediately to take up with Mr. E. H. Thompson, the owner of the Hacienda of Chichen, the proper location of the 100-acre tract provided for in the lease arranged by Dr. S. G. Morley several months earlier.

This having been completed, the next work undertaken, according to instructions, was the collection of building stone, palm leaves for thatching, and poles for the new house to be built in front of the *Casa Principal* as well as for the laborers' houses to be built to the south of the Park Chichen, and also a preliminary survey and study of the Group of the Thousand Columns.

A scale of 50 feet to one inch was selected for the map of the Columns, and this work was completed the latter part of January.

The principal work at Chichen Itzá during the 1924 field-season was the topographic-map of the site, which covers nearly a square-mile.

After several days of close inspection of the ruins in the Federal Archæological Zone, as well as those surrounding the Castillo for perhaps three-quarters of a mile on each side, an area was selected with the Castillo as the center; the border lines to extend as far therefrom as was deemed necessary.

It was found from the survey of the Group of the Thousand Columns, which was made on a scale of 50 feet to an inch, that a scale would have to be adopted that would show clearly a distance of from 4 to 8 feet—4 feet being the average width of walls of buildings and 8 feet being the average distance of columns from center to center.

Measurements taken on approximately 500 columns showed that they averaged 1.91 feet in diameter, while measurements on about 100 capitals gave an average of 1.70 by 2.12, and it was also found by a like number of measurements of distances between columns that they were not equally spaced, ranging anywhere from 7.70 to 9.90 feet in distance apart (center to center). According to the above figures, a scale of 1:2400 or 200 feet to 1 inch was selected. This later proved to be very satisfactory, for sufficient detail could be shown on each building so that it could be readily identified.

The next question of importance was the selection of a suitable contour interval. After taking several measurements of slopes and depressions and plotting these to scale, it was found that a contour interval of 5 feet would depict the country with sufficient accuracy for all purposes.

The above details having been decided, a point on the lowest step inside of the south balustrade of the west stairway of the Castillo (the best preserved of all) was selected as the starting point, and this was later tied into a position established on the platform of the Castillo by the Geodetic Commission of Mexico, in a scheme of triangulation extended over the peninsula in 1918. This position is 5 feet north of the west column in the entrance to the outer chamber of the Castillo, and is in latitude $20^{\circ} 41' 01.324''$ north and longitude $88^{\circ} 34' 09.444''$ west, and all projection lines are based upon it.

Positions of the points marking the corners of the Federal Archæological Zone were obtained from the Comisión Fomento and were plotted on the map to be used as control. These positions did not agree with plane-table positions in each instance, so an adjustment was made to take care of these errors.

The first line of traverse extended from the selected position on the lowest step of the west stairway of the Castillo, which was also used as the datum plane to which all contours and elevations are referred, along the roadway to the Hacienda Chichen, thence turning west and north following the trail past the Monjas and back to the point of beginning. The closure error on this line was very satisfactory and did not require adjustments. Distances were read to the nearest foot and elevations to the nearest tenth with a Gurley alidade and stadia rod graduated to hundredths of a foot.

With the completion of this circuit, a point in front of the Caracol and on the trail was used as a starting point and a line carried west to the border of the map, approximately 2,400 feet, and at intervals of 200 feet lines were cut north and south to the north and south borders. This method was repeated over the entire area which was gridironed into 200-foot squares. Plane-table stations were established at alternate intersections, and elevations were established midway of all lines and at angles to the center of squares inclosed by lines from this and other stations. It will be seen by the foregoing that every 1,600-square feet was controlled by 13 elevations. To get these elevations it was necessary to cut lines that totaled approximately 40 miles in length through the brush, which at times was so dense that it was possible to cut only half a mile a day with the aid of 8 men.

During the course of the survey it was found necessary to extend the borders of the map in each direction on account of new ruins discovered, which conflicted with the border line as selected with the Castillo as a base. This procedure, however, had to be abandoned when it was found that the borders could be extended indefinitely in each direction and still take in a ruin of some kind. The numerous ruins found during the survey were, to no little extent, covered with a heavy accumulation of débris and vegetation which rendered it very difficult to trace out their lines of construction.

In many instances the Maya seem to have selected a hillside and built to the level of the top, rather than construct an entirely artificial terrace. This was very confusing, for it made the tracing and location of contour lines difficult and indefinite.

The first carved stone found was that of a figure, presumably of a deity, in a sitting position, in the bottom of the dry cenote just to the west of the Monjas. This figure was almost completely buried in the sediment of the cenote and was either carved in situ or close by, or else it had tumbled from the ruin just above to the west.

The next stone was of the Chacmool type and was found just south of this cenote and west of a very much destroyed ruin about 200 feet away.

The third stone found was the head of a snake, in the process of being carved out, in a small artificial depression or quarry about 800 feet to the west of the south end of the Ball Court. This sculpture is of importance because it shows clearly the process of carving stone in the immediate vicinity where found. Judging from its location it would appear that the Maya obtained the major portion of their stone from ledges which had been broken up by natural processes, that is, by the breakage of the roofs of subterranean chambers and the exposure of a mass of dissected rock which was later fashioned into various shapes for building purposes.

The next stones of importance were two which had been carved into snake tails and shaped in a right-angular form; these were found about 400 feet

east of the slight angle in the road before entering the gates of the *planta* at the schoolhouse. The location of these stones would suggest that a building was in the process of construction somewhere, but there was no evidence of construction lines on this terrace.

Close by these stones, and a few hundred feet to the north, is found a tiger carved in deep relief on a rock ledge. There is no evidence of further cutting with the intention of removing this stone elsewhere.

The next, which conclude the list of important stones found, were those just east of the Federal Monument on the trail that leads to the Cenote of Sacrifices, on the Great Terrace. These stones are of a very heavy relief and show extensive use of feather decorations. There is no building close by that might suggest their provenance.

The most important group of ruins found outside of the Archæological Zone is that which has been designated the Northwest Group located north and west of the Great Ball Court. This group is remarkable for its deep and well-preserved carvings.

In the center of this group was found a small mound about 4 feet high, which resembles closely the tombs found directly in front of the Osario. With Mr. E. H. Morris, I trenched into the center of this mound to a depth of about 5 feet and discovered that it was not a tomb but presumably a sacrificial altar. The numerous mounds, temples, terraces, altars, and various other structures at this group are so extensive that they can not be described here, but will have to be covered in subsequent reports.

Measurements of the Great Terrace show that it contains an area of 47 acres and had been built up in some places to a height of 25 feet. On this terrace are located the major buildings—the Castillo, the Great Ball Court, and the Group of the Thousand Columns; and the lesser buildings—the House of the Eagles, the Tomb of the Chacmool, and a nameless structure.

Foremost among the interesting facts discovered in this group of buildings may be said to be the acoustic properties of the Great Ball Court. Tests made with the human voice, as well as with a small phonograph located in the North Temple, showed that the voice carried remarkably clear to the South Temple, 500 feet away, when a person was talking in a natural tone.

In a slight break in the south wall of the principal pyramid of the Group of the Thousand Columns, were revealed mural paintings of a dark red and yellow. This building is completely covered with débris and vegetation, and excavations here might reveal paintings and sculptures remarkably well preserved.

Numerous paved roads were traced leading away from the Great Terrace and in each case they appear to have been covered with plaster and flanked on both sides by low walls perhaps 2 feet wide.

Upon the completion of field work and after pointing out to Dr. Morley numerous features observed at Chichen Itzá and going over the area mapped, I left Yucatan on June 10, arriving in Washington on June 17. After a short leave of absence I returned to Washington to complete office work on the maps which were turned over to the Institution on July 24 ready for engraving.

Thanks are due to the many persons who assisted in various ways in all this work, and especially to Mr. W. M. James, of Merida, and Mr. O. Gaylord Marsh, American Consul at Progreso, who so kindly extended their services whenever needed. Thanks should also be expressed to the United States

Geological Survey for its coöperation in this work and the numerous facilities which it has extended.

Report of Mr. Frans Blom on the Preliminary Work at Uaxactun, Guatemala.

The eighth expedition of the Carnegie Institution into the Department of Peten, northern Guatemala, left Belize, British Honduras, for El Cayo, the head of navigation on the Belize River on February 18. The object of the expedition was to make a survey of the ruins of Uaxactun, discovered by the expedition of 1916, and to prepare the site for exploration during the coming years.

El Cayo—the chicle and mahogany center on the Belize River—is the starting point for all expeditions wishing to penetrate the immense tropical forests of northern Guatemala. It was reached on February 21. Pack-mules were secured and final touches were put to the outfit. Plancha de Piedra, the Guatemala customs station, was reached on February 25, and the following day 22 saddle and pack animals and a gang of laborers on foot swung into the narrow forest trails. Four days brought the expedition to its destination.

Mr. O. G. Ricketson, who had previously been at Uaxactun, accompanied the expedition in order to acquaint the leader, Mr. Frans Blom, with the ruins and monuments. As soon as this was accomplished he returned to British Honduras.

Dense vegetation covered the site, and it was necessary to clear this in order to erect houses, roofed with palm leaves, for the members of the staff and the workmen. A large water-reservoir had to be dug in the water-hole, which generally dries up during the month of May. As soon as a camp was established and trails had been cut to the different groups of buildings, a plane-table survey of the ruins was commenced. Mr. Monroe Amsden started this work but, as he soon had to leave because of illness, it was completed by Mr. Blom.

Toward the close of April, work at Uaxactun was concluded and the greater part of the equipment was sent direct to Plancha de Piedra. Mr. Blom, with some Indians, proceeded to various other ruins in the Department, finally reaching El Cayo on May 18. The sites visited were Tikal, Mejia (new), Ixlu, Flores, Tayasal, Chichantun, Yaxha, Topoxte, Benque Viejo, caves near Benque Viejo, Nakum, El Encanto, Holmul, Tzotzkitam, and Baking Pot, the last in British Honduras.

Though the primary purpose of the expedition was to prepare for more intensive work at Uaxactun, a large amount of archæological information was collected.

All the monuments at Uaxactun carrying inscriptions were drawn. A comparison of these drawings with those previously made by Dr. Morley made it possible to definitely decipher several formerly doubtful dates. Stela 5 at last gave up the secret of its date, the reading being a Baktun 8 Initial Series, 8.16.1.0.12. Dr. Morley had previously given the tentative reading 8.15.18.3.12. This final reading gives a third Baktun 8, Katun 16 date at Uaxactun.

On a fragment of Stela 14 the date 8 Ahau 18 (?) was found; this may well be 9.19.0.0.0 8 Ahau 18 Mol, the same date as given by the Initial Series on Stela 7 here.

The plane-table survey disclosed several important features, among others the close relation between Groups A and B, through an inclined road connecting the main plazas of the two groups. This road emphasizes the importance of the main plaza of Group A. The mound at the southern side of this plaza appears to be the heart of the two groups. This mound faces north, and from its top one looks down upon the main plaza of Group A and a row of monuments including Stelæ 7, 8, and 11. The oldest stela known stands on the northern side of this plaza, and to the north of it begins the road already mentioned, sloping down to the main plaza of Group B, with its multitude of monuments—a most imposing sight in ancient times.

During rainy days the large temple standing at the northeastern corner of the Acropolis (Group A) was cleared. The floors were covered with several feet of fine dust, and this was removed. Two rooms in the western end of the temple were nearly filled with débris, and when cleared the more western of these was found to contain a stairway turning at right angles and leading to the roof of the building. Only one other such stairway had been previously known, that discovered by Dr. Morley at Quirigua. This building is in such a good state of preservation that it will be used for staff quarters.

On the lowland close to the aquada a quarry was found, which shows distinctly where the ancients had cut a limestone block for a stela. The road connecting Group A with Group D, as well as other roads connecting the different parts of Group D, was also found.

By far the most important discovery was made in Group E, namely, what appears to be an observatory for studying the sun. The group consists of terraces on which are mounds, the terraces being arranged around a plaza. The eastern terrace has three mounds upon which are remains of temples (I-III) with stairways leading from the plaza. In front of this terrace are Stelæ 18, 19, and the plain stela, F.a. Whether we really have an observatory here can not be determined until the group has been excavated and studied with precise instruments. The figures at hand speak in favor of an observatory.

On the western side of the plaza we found Mound VII, likewise crowned by the remains of a temple facing south. On the side of this mound toward the plaza stands Stela 20. This plaza was covered with dense vegetation, and as the work of clearing proceeded it became more and more apparent that there was a close relation between Mound VII and Stela 20, and the eastern terrace, with its three mounds and three stelæ.

The Department of Terrestrial Magnetism has located the geographic position of Uaxactun as latitude north $17^{\circ} 23' 8''$, and longitude west $89^{\circ} 38' 4''$. The bearings within the group were taken with a Brunton Pocket Transit from a position directly behind (i. e., west of) Stela 20. The magnetic declination is 7° and was corrected on the compass, so that all readings were taken direct. A line drawn between Stela 20 and Stela 19 turned out to be due west-east, cutting through the center of Temple II.

Sights were also taken from Stela 20 to Stelæ 18 and F.a., the bearings being N. 76° E. and S. 76° E. respectively, and finally sights were taken over the centers of the Mounds I and III, giving the bearing N. 66° E. and S. 66° E., or 24° north and south of the west-east line. Comparison of these angles with the following data furnished by the Department of Terrestrial Magnetism shows amplitudes for sunrise at Uaxactun in latitude 17°

23' 8" north and longitude 89° 38' 4" west of Greenwich extreme values during the year.

True horizon.	Visible horizon.	Remarks.
°	°	
24.6	24.4	North of east on June 22.
24.6	24.9	South of east on December 22.

We see that the lines of sight from Stela 20 to Stelæ 18 and F.a. are 24° north and south of the true east, coinciding with the two extremes at which the sun rises during the year.

Turning to the dates on the three stelæ in Group E, we see that Stelæ 18 and 19 carry the same date, viz, 8.16.0.0.0 3 Ahau 8 Kankin (97 A. D.) and Stela 20, the date 9.2.0.0.0 2 Ahau 18 Muan (235 A. D.). If Group E really proves to be a sun observatory it must have been erected not later than the year 235 A. D. and have been planned long before the two earlier stelæ were set up. Excavation of this group may throw much light upon Maya astronomy; it may be possible to find other lines of observation, and to determine the unit of measurement used, etc.

A hitherto unknown group of huge mounds was located south of Group E, and called Group F. A large natural hill had been leveled and terraced. Mounds inclosing courts and remains of several buildings were found, but no monuments.

*Report of Mr. O. G. Ricketson jr., on the Excavations at Baking Pot,
British Honduras.*

The excavations carried out during the season of 1924 at Baking Pot were under the direction of Mr. Oliver Ricketson jr., who sailed from New Orleans on February 10, proceeding to Belize, British Honduras, when he accompanied Mr. Blom and Mr. Amsden to the ruins of Uaxactun, Guatemala, returning immediately to Belize to outfit and provision.

Baking Pot lies on the south bank of the Belize River, 6 miles by land easterly from El Cayo. The ruins consist of two distinct groups lying in a large clearing, belonging to Mr. Arthur Williamson of Belize, to whom the expedition is greatly indebted for many courtesies.

Dr. Thomas Gann, by a careful study of Cogolludo and Villagutierre Sotomayor, and aided by a first-hand knowledge of the topography and drainage of the country traversed by Avendaño, Fuensalida, and Orbita, has concluded that the Tipu mentioned in these accounts must be the ruins located at modern Baking Pot, since no others in that vicinity fulfill the requirements as to size, location, and stated distances. As Tipu was the location of the first Franciscan mission in what is now British Honduras, it was hoped that the discovery of its remains might positively identify the site as Tipu. The almost innumerable small mounds that dot the whole clearing, however, uniformly offered such a smoothly rounding appearance that a far more exhaustive study would be necessary to determine the actual presence or absence of such a mission.

Excavation started March 23, four different sites being examined. The first site was a small house-mound to the north of Group 1, consisting of a

rectangular platform of faced stone. The finds were coarse sherds, broken granite mauls, and a few flints.

The second site excavated was the top of the most prominent pyramid (Pyr. B) in Group 1. This group lay with its long axis east and west, a quarter mile to the north of Group 2 and 250 meters from the nearest bank of the river. It consisted of three built-up plazas, Plaza 1 being the lowest and westernmost, Plaza 2 (separated from Plaza 1 by the centrally located Pyramid B) being the medial one in both position and elevation, and Plaza 3 being the easternmost and highest. Both axes of the top of B were trenched to a depth of over a meter. No worked stone and only a very few natural rocks were found. Sherds were conspicuously absent.

Excavations at the third and fourth sites were started simultaneously. One of these was the top of a small pyramid (E) placed centrally on a mound running north and south between Plazas 2 and 3. It was composed entirely of unworked limestone and limestone marl. A cache of 9 eccentric flints and 2 small jade pieces was uncovered.

The last site to be described is a steeply sloping, circular mound (G), lying on the northern edge of Plaza 3, 4.5 meters high and 26 meters in diameter. Excavation revealed a rectangular retaining wall of faced limestone with slight lateral projections, the wall curving up from each corner (where the average height was less than 1 meter) to the midpoint of each side (where the average height was 1.75 meters). On the south side close to the southwest corner, but lying outside the retaining wall, 3 skeletons were found, all lying parallel to the wall. Burial 1 lay face up, was male, and lacked the right arm, the pelvis, and both legs; the burial objects were a piece of antler, a corn grinder, and grinding stone. Burial 2 was also face up, the right leg fully extended, but flexed at the hip so that the foot lay above the head; the right femur's greatest length was 43.6 cm. The left leg was missing, though the head of the femur was in the acetabulum; no burial objects were found. The head of Burial 3 lay directly beneath the pelvis of Burial 2. It showed marked fronto-occipital flattening, and was the only cranium unbroken. All three burials were simple inhumation.

The mound was then trenched from the south side to the center. Inside and above the retaining wall another wall was encountered. This was also of faced stone, and sloped upward from the corners to the midpoint. Lying parallel to this wall and just outside it, another skeleton was uncovered, face down, simple inhumation, and no burial objects.

Continuing the trench to the center, Burials 4 and 5 were encountered, No. 4 lying directly over No. 5, at a depth of 1.37 meters. Both lay face down, head to the south, as did all of the other 8 skeletons found at the top.

Just beyond Burials 4 and 5 a sepulcher was found, lined with faced stone and covered with flat slabs of rock. In endeavoring to trench around the east side, 7 skeletons were uncovered. Of these the following peculiarities may be noted: No. 7 had a deformed left humerus (25.3 cm. as opposed to 31.6 in the right) and an enlarged head and great tuberosity on the left femur; No. 8 had five and one-half of the upper front teeth deeply filed; No. 11 was directly superimposed on No. 13, the latter, besides other objects, having a large and deformed antler, drilled and grooved, under the mandible; No. 12, directly superimposed above No. 14, had the upper front teeth filed as in the case of No. 8. No. 14 still retained the deciduous teeth; its cranium lay

below the pelvis of No. 12; the sciatic notch of the latter enabled identification as a female.

Burial 15 occupied the central grave of stone. The upper 5 front teeth were inlaid with circular fillings of iron pyrite on their anterior surfaces. There were 2 three-legged pots, that at the head being incised with a plaited design, the one at the feet being plain; both were black. Other burial objects were 5 jade beads, 2 jade ear-plugs, and several pieces of carved bone and shell. The bones were badly decayed, yet the left shaft of the femur was sufficiently preserved to show clearly lesions closely resembling the involucrum of syphilis, if not syphilis itself. Many of the 12 crania obtained when assembled will undoubtedly show marked fronto-occipital flattening.

Work was concluded May 31 and Mr. Ricketson proceeded to Chichen Itzá, returning to the United States in July.

Van Deman, Esther B., Rome, Italy. *Associate in Roman Archaeology.* (For previous reports see Year Books Nos. 9-15, 20, 22.)

The first half of the current year, to which the present report is confined, was divided almost equally between the preparation for publication of a portion of the text of the historical section of the introduction to the general Handbook, the completion of the article on the House of Caligula,¹ referred to in the last report, and the architectural reconstruction of the Neronian Sacra Via, the general discussion of which was published in 1923.²

The portion of the Handbook to which the first three months of the year were largely devoted included the rise and history in general of the use of the more important building materials, both natural and artificial, with their first appearance in Rome, and the discovery of the principle of the true arch, more especially with reference to its ultimate development in the concrete vault and dome of the Roman period. In connection with this investigation, lists of the existing remains of sun-dried brick monuments outside of Rome, so far as at present reported, were prepared for publication. A considerable body of new evidence has been discovered concerning the natural materials, much of which will be of value in the final revision of the chronological list of the Roman monuments, now approaching completion. The determination of the date of the introduction of certain of the foreign stones, especially those intended for architectural decoration, has been especially fruitful in results. The general review of the origin and development of the use of the various artificial materials, which is now practically ready for publication, has proved of great value, more especially in its bearing upon the later history of sun-dried as well as of kiln-dried brick and concrete at Rome. While the extensive use of sun-dried brick as a building material in the valleys of the Euphrates and of the Nile in very early times is well known, the important place held by them in the later periods, not only in these lands but in the western world as well, has been but little appreciated. Their occurrence in Greece, even during the better periods, not alone in private houses but in public structures, such as city walls and temples, is, however, not only referred to by ancient writers but proved conclusively by modern excavations. In Italy also, recent years have brought to light a few scanty remains of sun-dried brick structures in Rome itself, as well as a considerable stretch of the famous city wall of Arezzo (Arretium), made of the same materials, which are mentioned by Vitruvius. Various opinions prevail concerning the people to which the discovery—or invention—of kiln-dried bricks, whether for walls or roofs, is to be assigned. Although they appear at a very remote period in Egypt as well as in Babylonia, the weight of evidence furnished by modern excavations, so far as reported, seems rather on the side of the land of the Euphrates, the great center of brick construction through many ages. In their later history, Greece played, it is clear, but a little part, since, until Roman times, kiln-dried bricks were not used there normally, except for roof and floor tiles, in which form only they appear also in republican Rome. In neither of these classical lands do "brick walls" in the modern sense occur, although, as an external casing, or facing, bricks form the most conspicuous, though not the most important, part in the typical construction of the Roman world, brick-faced concrete. The use of rubble, with both clay and lime mortar, as a build-

¹ *The House of Caligula*, Amer. Jour. Archæology, 1924, pp. 368 to 398.

² *The Neronian Sacra Via*, Amer. Jour. Archæology, 1923, 4, pp. 383, 424, pls. III-IV.

ing material is very ancient. In the last centuries before our era also, a type of construction, best distinguished as pseudo-concrete, appears in several places which resembles, though in a cruder form, the later true concrete. Since, however, no certain examples of true concrete, either pre-mixed or laid, have been seen or reported earlier than the last quarter of the second century B. C., at which time it appears in Rome, the invention of concrete, so far as we are able at present to determine, must be attributed to the Romans. While it is evident that the discovery of the principle of the true arch must be assigned to an older civilization than that of Greece or Rome, it is no less clear that to the latter belongs the honor of first bringing that principle to its full development in the great vaulted monuments of the imperial times, the model and fore-runners of medieval and modern vaulted structures.

The discussion of the House of Caligula has been limited, in the present article, to a detailed description of the remains belonging to the periods previous to and including that of Caligula, with only a brief resumé of the important discoveries made concerning the monuments by which it was replaced. Of the famous building of Caligula, by which he "extended the Palatium to the Forum," but a few fragmentary walls and a broken water-basin, or piscina, have been recognized up to the present time. The portion of the new palace now identified and which may be accepted as certain is composed of a huge peristyle in the rear of and originally connected with the temple of Castor, and of an extensive reservoir for water, three stories high, on the slope of the Palatine above. The remains of the peristyle which still exist in part or are traceable consist of the travertine foundations of four pillars on the north and a like number on the west side, belonging to the colonnade, and a considerable portion of the outer wall on the east, with the greater part of the water-basin in the center of the building, though in a later restoration, probably of the period of Claudius. The reservoir, or cisterna, which has been discovered behind and beneath the later structures of Domitian and Hadrian at the northwest corner of the Palatine, forms a solitary block of concrete vaulted chambers 20 to 20.5 meters (70 Roman feet) in length, and over 23 meters (78 Roman feet) in width, the west end of which has been cut off by the imperial guard rooms of the time of Domitian. This structure consists of two stories, each containing a large hall, or corridor, on each side of which are three smaller rooms; above these rooms is a huge open basin connected with the reservoir below by square openings in its floor. While the topographical value of the discovery of this building is not small, its importance for the history of construction is still greater, since in the absence of any other remains of the great monuments built by Caligula, our knowledge of the construction of the period must be based solely upon it.

In connection with this discussion a brief summary has been given of the general character and date of the several structures by which the house of Caligula was replaced or destroyed, especially of the so-called temple of "Augustus," and the imposing ramp by which it was connected with the Palatine. The most important of the results noted in the preliminary review are the assignment to the period of Hadrian, (1) of the colonnade around the "temple of Augustus," itself the work of Domitian, (2) of the great ramp connecting that building with the Palatine above, and (3) of the entire group of structures extending from the so-called "bridge of Caligula" to the Nova Via; and secondly, the identification of the rooms on the east of the upper clivus Vic-

toriæ as a part of the quarters of the imperial guard, of which the "bridge of Caligula" formed the front.

The lack of time and the mass of material involved rendered it necessary to limit the formal discussion of the new quarter erected by Nero along the Sacra Via, which was published in 1923, to the historical and structural treatment of the remains. During the winter of 1923-24, with the invaluable assistance of Albert G. Clay, Fellow of the School of Architecture of Yale University, a rigorous examination of the scattered architectural fragments was undertaken with a view to the reconstruction of the lofty arcades on either side of the Neronian Sacra Via with the great covered halls in their rear. The architectural remains identified include some dozens of voussoirs belonging to the arcades, 17 of which retain portions of the original decoration, a number of fragmentary pillars, with a part of the circular stairs belonging to the Colossus of Nero. The reconstruction, which formed a part of the Annual Exhibition of the American Academy of the current year, will appear in the next volume of the Memoirs of the Academy.

During the progress of the work connected with the reconstruction of the Sacra Via, the remains of a number of new monuments or parts of monuments were identified. Among the most important of these are the façade of the vestibulum of the Golden House and the upper portion of the Neronian porticus along the clivus Palatinus, the northern part of the original house of Augustus on the Palatine, and the front line of the domus Augustana of the periods of Nero, Domitian, and Hadrian. At the lower end of the Sacra Via, remains of the flight of steps were discovered also, leading up to a porch, or *terrazza*, in the rear of the temple of Julius Cæsar, the existence of which has not before been suspected.

Renewed thanks are due to the American Academy in Rome for the use of its library, as well as to the various members of the staff, especially to Director Gorham P. Stevens and Professor John C. Rolfe, head of the Classical School, to whose kind assistance and wise counsels much of the success of the work of the year is due.

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Preparation and publication of the Index Medicus. (For previous reports see Year Books Nos. 2-22.)

In the third volume of the current series of the Index Medicus (that for 1923), there are 55,341 references to book titles and journal articles covering 1,113 pages, while the author index comprises 113 pages. The corresponding figures for the preceding year were 1,050 and 111 respectively. This is a slight increase in size of the last volume over its predecessor, but such increase is not proportionate to the increase in the literature constituting the sources from which the material is drawn.

Noticeable changes have taken place in the past twelve months regarding literature relating to medicine and its allied and associated sciences. Thus, there has been seen the reappearance of writings in the Russian and Polish languages in considerable volume. Not only so, but critical examination of such contributions indicates that the research work and clinical observations upon which they are based are of a high order. Russian medicine must be assumed to have preserved, either intact or not seriously damaged, most of the fine scientific traditions which characterized it in pre-war days. This is very comforting, in view of fears so often expressed in the English-speaking world that Slavic science had suffered fatal injury in the period of economic and political flux which the Russian nation has been undergoing. Again, it may be stated in fairness that the quality of the medical literature throughout the civilized world has much improved. Following the World War many pens were very busy, but their products were characterized in too great measure by an easy verbosity that served more to obscure than to clarify such real truth as they might have contained. To-day this is changed, and we find that in ever-increasing measure the literature of medicine reflects substantial progress which carries with it an augury of good for the human race and a promise of greater relief in the future from physical ills.

The Index Medicus still purports, as in the past, to serve as a clearing house for this great mass of the recorded results of medical and surgical research in its practical entirety.

BIOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-22.)

Investigations have been continued on the genetic constitution of rabbits, rats, and mice, with especial reference to linkage. In rabbits three genes have been shown conclusively to lie in one and the same linkage system (chromosome). These are (1) *English spotting* and (2) *Dutch spotting*, which lie in or close to the same genetic locus, and (3) *Angora coat*, which shows 13.7 ± 0.9 per cent of crossing-over with English, and 12.7 ± 1.4 per cent of crossing-over with Dutch. Experiments are in progress to determine these relations with greater precision, which can be done only by producing larger numbers of offspring from pedigreed animals. Improvements in technique and methods of feeding have enabled us to produce about 4,800 rabbits in the last 11 months in connection with this and other experiments.

A second linkage system has been discovered in rabbits, with about 40 per cent of crossing-over. No linkage so "loose" as this has previously been observed in a mammal. Although on our present data, the linkage exceeds four times the probable error, it seems desirable to withhold definite announcement of this case until it has been fully established by more extensive observations.

Several short papers have been published during the year, as shown in the bibliography. A monograph on heredity in rabbits and guinea-pigs has been prepared for the editors of *Genetica*, summarizing present knowledge of the subject. Also a third edition has been prepared of the text-book, *Genetics and Eugenics*, in which has been incorporated much of the experimental work of the author during the last 20 years, as Research Associate, a relationship which alone has made those investigations possible.

Crampton, Henry E., Barnard College, Columbia University, New York, N. Y. *Continuation of field investigations on the variation, distribution, and evolution of species of the Genus Partula.* (For previous reports see Year Books 7-10, 22.)

The year has been devoted to the further analysis of the collections of *Partula* from Moorea, Society Islands. While the Moorean research deals with the same problems as the study of the Tahitian species (Publ. No. 228), the results are far more significant, inasmuch as constitutional and geographic changes in species and varieties have been demonstrated for two sequential periods, namely, for the interval from the later decades of the nineteenth century to 1907, and for the period from 1907 to 1924. In brief, the reality and nature of varietal differentiation have been definitely proved in numerous and mutually confirmatory instances.

Two papers on important topics within the whole research have been published as follows: *New and significant species of Partula from Moorea, Society Islands* (Nautilus, vol. xxxvii, Apr. 1924), *The coincident production of dextral and sinistral young in the land-gastropod Partula* (Science, vol. lix, No. 1538, June 20, 1924). A third paper with illustrations, soon to appear in the American Naturalist, gives a general statement of the qualitative results

of the Moorean studies, under the title *Contemporaneous organic differentiation in the species of Partula living in Moorea, Society Islands*.

A volume on the species inhabiting the Mariana Islands was completed for publication by the Bishop Museum of Honolulu, but its publication has been undertaken by the Carnegie Institution.

The summer of 1924 was devoted to a final field-journey to Moorea, for the purpose of completing the study of certain critical areas.

Crozier, W. J. Rutgers University, New Brunswick, New Jersey. *Biological researches relating to the nervous system.*

In January 1924 the Trustees of the Carnegie Corporation of New York appropriated a sum of \$5,000 to the Carnegie Institution of Washington for the purpose of enabling Dr. Crozier to carry forward his biological researches relating to the nervous system; whereupon Dr. Crozier was appointed a Research Associate of the Institution for the year 1924.

The general question under investigation has to do with the intimate nature of central nervous activities. Up to the present time this has represented a great gap in the knowledge of animal conduct, and one necessary to fill before the interpretation of behavior can make much progress. The procedure has involved the utilization for quantitative study of some process which could be proved to be a measurable function of central nervous action. Several alternatives were considered, notably the probability that a "central effect" might be detectable in properly chosen instances of phototropism. The results of this inquiry are in course of publication. A most suitable phenomenon, however, was found in the "death feigning" of arthropods. Considerable attention was given to the proof that the duration of an act of reflex tonic immobility ("death feigning") is due to the duration of a central nervous state (analogous to synaptic transmissivity).

Analysis of the relationship between duration of induced immobility and temperature showed that the duration was an exponential function of the temperature (equation of Arrhenius), but that in the two zones of temperature on either side of 15° C. the critical thermal increment was different. Details aside, it was established that the duration of an act of immobility appears to depend upon the amount of a substance, *B*, formed and decomposed in a system of reactions of the type $A \rightarrow B \rightarrow C$, in which the two linked reactions have dissimilar temperature coefficients or critical increments. This conclusion rests (1) upon the exact form of the curve of successive durations of immobility in repeated trials; and (2) on the magnitudes of the temperature characteristics, which are those associated with certain types of chemical reactions.

This mode of treatment has the advantage that it permits a conclusion stating that chemical transformations control the activity of the central nervous tissues in the instances studied, but involves no knowledge of the kinds of reacting substances. The possibility that one might be dealing with "amoeboid" movements of the terminal arborizations of neurones has been apparently excluded by the result of a special study of the movements of the alga *Oscillatoria*, presumably dependent upon the activity of a surface layer of protoplasm similar to that on the surface of amoeboid cells and, in *Oscillatoria*, especially suitable for investigation.

Examination of available data on "synaptic resistance" in the spinal cord of vertebrates leads to conclusions consistent with the foregoing. It became then of general interest to discover a method which might permit identification of the reactants, or at least the chemical classification of the reactions. This phase of the work has involved the re-investigation of practically all published data upon the relations between temperature and the velocities of biological phenomena, as well as a careful new study of certain selected processes not hitherto discussed from this viewpoint. The result, briefly, has been that vital processes fall into definite groups, depending upon the magnitudes of the critical thermal increments.

The critical increment signifies, physically, the amount of heat required for the chemical activation of one gram molecule of the reacting substance. The actual findings become intelligible if one assumes, with F. O. Rice, that processes exhibiting the same critical increment do so because this constant has reference to the formation of active molecules of a common catalyst. In the case of the extremely important group of processes dependent upon cell respiration, it is possible to demonstrate that this theory is consistent with all known pertinent facts, for the common catalyst and its critical increment are independently identifiable.

From this standpoint it becomes possible to construct a rational classification of inner processes concerned in the determination of animal conduct, and, in a number of cases, it is permissible to specify the catalysts which control the fundamental chemical transformations. With reference to the initial problem of immobility in arthropods, it is concluded that the two linked reactions revealed by kinetic considerations are catalysed respectively by OH ion and by H ion.

The extension of these views will presumably serve to remove the basis for cruder forms of mysticism in the interpretation of central nervous processes. It is especially important that the method of experimentation is very simple and involves no destructive interference with the living matter.

Kofoid, Charles A., University of California, Berkeley. *Investigation on intestinal protozoa.* (For previous report see Year Books Nos. 21, 22.)

During the past year in conjunction with the California State Board of Health and the assistance of research grants from the Board of Research of the University of California, and in collaboration with Dr. Olive Swezy, researches have been actively prosecuted on the incidence of human intestinal protozoan infections and their relationship to disease.

Investigations have been continued on the relationship of human amœbi-asis and *Arthritis deformans* of Ely's second type in collaboration with Dr. L. M. Boyers and other physicians having in charge patients suffering from amœbic infections. The result of these contacts is a widening concept of the range of clinical signs which attend human intestinal protozoan infection, especially those by *Endamæba dysenteriæ*. There is increasing evidence of organ infection involving mesenchymal structures and suggestions of local acclimatization and perhaps of mesenchyme affinities of *Endamæba dysenteriæ*. Studies have been carried forward on the relation of amœbæ to skin ulcers and to the general problem of tissue invasion.

Additional cases of Hodgkin's disease accompanied by coincident amœbi-asis of the colon have come to light.

The serological relations of protozoan infections have been attacked by culture methods. Definite intradermal skin reactions of cultures of *Leishmania tropica* and *Leishmania infantum* have been secured by Mrs. Wagener, and in the rabbit and guinea-pig by Miss Koch. A precipitin test has also been secured by Mrs. Wagener in cases of experimentally induced amœbiasis in cats. Successful culture methods for both flagellates and amœbæ of the bowel have been instituted along the line of recent work of Boeck and on other lines.

We have detected three cases of infection of the intestine of man by an amœba, *Karyamæba falcata*, which proves to belong to a genus distinct from any hitherto found in man. It has been observed over a period of several months and is characterized by large numbers of chromosomes and a peculiar type of mitosis which allies it to the widely known free-living and parasitic genus, *Vahlkampfia*.

We have assembled in one paper jointly with Dr. Swezy and Dr. Kessel the characterizing features of the genus *Councilmania*, an amœba parasitic in man and the rodents, and have separated the species, two of them occurring in the rat and mouse, and the third in man, although the latter may be experimentally introduced into both the rat and the mouse.

In conjunction with the Stomatological Group at the University of California working under a grant from the Carnegie Corporation on the problem of pyorrhœa, we have made a critical comparison of the amœbæ of the teeth, with *Endamæba dysentericæ* from the stools, from the wall of the bowel, and from various human tissues, and also in culture animals. We find distinct nuclear characteristics which will make possible the critical distinction of the amœba of the subgingival region of diseased teeth in the human mouth, *Endamæba gingivalis*, from *Endamæba dysentericæ* which infects the colon and is carried thence by the blood-stream to other organs of the body. This critical survey makes it certain that the amœba in the bone marrow in *Arthritis deformans* of Ely's second type is not an invader from diseased teeth, but rather from the colon in intestinal amœbiasis.

Studies have also been made by Mrs. Wagener and Miss Thomson on the experimental infection of cats with *Endamæba dysentericæ* from chronic and non-dysenteric cases of human amœbiasis, with the results that the amœbas from these types of this disease are with difficulty, if at all, inoculable into the kitten. It has also been determined that induced cases in the cat of acute amœbiasis, when followed by recovery, are accompanied apparently in a complete elimination of the parasite.

Dr. Bercovitz has completed his studies on the effect of various disinfecting chemicals and laboratory reagents upon the cysts of the amœbas of the human bowel. This work demonstrates the necessity for more critical criteria for determining the viability of amœbic cysts than has hitherto been established.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.* (For previous report see Year Books Nos. 18-22.)

During the past year the diatom investigations have been more extensive and satisfactory than in previous years, because of an increase in laboratory help, Mr. P. S. Conger having been employed throughout the year and Mr. L. B. Copeland from October 1 to June 30. As a result, although requests for

research work have been greater than ever before, all have received attention. Forty-three samples of fossil diatom material have been sent in for study and report: 13 from Virginia, 11 from Oregon, 3 from Florida, 3 from Nevada, 2 each from Tennessee, Texas, San Salvador, Denmark, and Venezuela, and one each from Alabama, New Mexico, Utah, Washington, and New Zealand, thus covering a wide range of territory and of geological formations. Fifty-three of the samples submitted were of recent material; 15 from California, 9 from Massachusetts, 7 from Maine, 9 from Laysan Island, 5 from Lisianski Island, 4 from Johnson Island, and 4 from Wake Island.

In addition to the foregoing, over 100 samples of marine diatom life were collected at Woods Hole, Massachusetts, during 5 weeks' work and prepared for further examination, this being the seventh consecutive year of study there in cooperation with the U. S. Bureau of Fisheries. Plans are already matured for continuing these useful researches during the summer of 1924.

One of the investigations mentioned deserves special remark, that of some fossil material discovered near Spokane, Washington, which proved to be very unusual in character and yielded quite a number of species never before found in America, as well as several wholly new species. A report, with micro-photographic illustrations, will appear in a monograph by Dr. F. H. Knowlton of the National Museum upon certain plant fossils found in the same locality.

A set of test diatoms for determining the optical quality of microscopes was made for the Central High School of this city.

McCracken, Isabel, Stanford University, California. *Studies in silkworm bionomics*. (For previous report see Year Book No. 22.)

During the current year, in pursuance of the plan previously laid down for a study of the "bionomics of the silkworm," over 100 broods of this insect were reared in experimental lots, in addition to a large number of broods of "pure" stock, during the breeding season of this insect (April to September). Tabulation and study of data gathered at this time is now under way. As this data is analyzed and its significance examined, the results will be published elsewhere.

On account of its economic importance the silkworm has been subjected, in France and Italy particularly, to a very considerable amount of general observation and study which forms an invaluable fund of information for a student of its bionomics. An exhaustive study is being made of this literature.

In spite of the great amount of critical study that has been devoted to this insect, there are many points in its biology of which, for the purpose of the experimentalist, we have insufficient information. These relate to the life span of different races, irregularities in hatching, molting, in cocooning, duration of life, etc. A complete biological study is therefore being carried on, side by side, with the gathering of experimental data, and much interesting information is being accumulated. In addition, before certain bionomic questions can be submitted to experiment, certain genetic conditions must be better understood.

For example, in the study of the genetic relation of color as it affects egg, blood, and cocoon, an examination of hundreds of broods and many thousands of eggs shows that color is a factor affecting larval and adult blood, cocoon color, and color of eggs characteristically. A larva with apparently colorless

blood (white), as has become well known from previous investigations, forms a white cocoon. A white-blooded moth arising from the pupa of such a larva oviposits light creamy eggs which, upon assuming their winter color, are within the "neutral gray color series" (Ridgway, *Color Standards and Nomenclature*), but under certain conditions with a very small percentage of color, namely, yellow, which throws them into the "purplish gray" series. What are the conditions which thus modify the color? This is a subject for experiment which is under consideration.

A larva with yellow blood spins a cocoon in the yellow or buff series. A yellow-blooded moth from such a larva lays "yellow" or "golden" eggs. These eggs upon assuming the winter color, characteristic of the univoltin silkworm, lie in the "mouse-gray" series of color. In broods examined, the egg-color is uniform for the brood but varies between broods from the proportion of 4.5 per cent color to 95.5 per cent non-color, or neutral gray, to 100 per cent color. In the former case the eggs assume a dark neutral-gray appearance and in the latter case a dark olive-gray appearance. Again, what are the conditions which thus modify the color?

Larval spinners arising from such groups of eggs spin yellowish, buffish, or white cocoons, according to their genetic tendencies. The yellowish and buffish cocoons, however, are far from uniform. A study is being made of this non-uniformity.

Table I gives in detail the result of an analysis of the cocoon color in one such brood, the eggs of which were apparently mouse-gray in color.

TABLE I.

1 Cocoons.	2 Cocoons.	3 (tint). White : color.	4 (shade). Color : gray.	5 (hue). Orange : yellow.
No.	Per cent.	Per cent.	Per cent.	Per cent.
6	2.7	45 - 55	68 - 32	47 - 53
18	8.1	45 - 55	72 - 58	47 - 53
10	4.5	45 - 55	100 - 0	47 - 53
18	8.1	22.5 - 77.5	68 - 32	47 - 53
76	34.5	22.5 - 77.5	68 - 32	25 - 75
92	41.8	22.5 - 77.5	42 - 58	47 - 53
Total 220				

Thus cocoon color is independent of the color of egg from which the larva spinning it arises, but its genetic significance calls for further examination.

An analysis is being made of the variation in many such broods with reference to their conditions of breeding and genetic history, preparatory to using results in further steps to be taken in this study.

Morgan, T. H., A. H. Sturtevant, and C. B. Bridges, Columbia University, New York. *The constitution of the germ-material in relation to heredity.* (For previous reports see Year Books Nos. 15-22).

One of the problems that we have long had under consideration involves the sequence of the genes in related species. The most direct attack on this problem would be by means of fertile species hybrids. So far no sufficient study has been made in the case of hybrids where the linkage relations in

either parent (or in both) were adequately known. No fertile species hybrids of *Drosophila* have been found, and to date only two species, *D. melanogaster* and *D. simulans*, have given any offspring at all when crossed. When, as in this case, the hybrid offspring are sterile, it is necessary to obtain mutants independently in each species in order first to identify, by crossing, those that represent corresponding changes and, secondly, to discover whether the sequence of the corresponding genes is the same in the two species. In the present case the problem has resolved itself into finding mutant characters in *simulans* for comparison with known characters in *melanogaster*. About 50 such characters have appeared, and of these 20 have been shown to correspond to known mutant types of *melanogaster*. On this basis the maps of the two species may be compared in some detail. The list of known corresponding genes in the X-chromosome of *D. simulans* now reads: yellow, prune, white, ruby, cross-veinless, vesiculated, singed, dusky, garnet, rudimentary, forked, fused, bobbed. These cover the entire known length of the X in both species, and they are so favorably located with respect to each other that it is now possible to determine the linkage relations in *simulans* without the necessity of making corrections for undetected double cross-overs. Such a study has been almost completed. The result shows that the 13 corresponding genes have the same sequence in the two species. While the various intervals differ somewhat in their cross-over values, the coincidence relations are apparently very similar. Four corresponding genes are known in chromosome-II, but the linkage relations are not yet sufficiently studied in *simulans* to make a detailed comparison of the maps possible. There are three corresponding genes in chromosome-III: the sequence in *melanogaster* is scarlet, peach, Delta; while in *simulans* it is scarlet, Delta, peach. Several new mutant types not yet thoroughly tested will probably enable us to make a more thorough analysis of the rearrangement that has occurred in this chromosome. A similar rearrangement is suggested by the work of Metz, Lancefield, and Weinstein in other species of *Drosophila*; but, since none of these species can be crossed, the identification of corresponding genes is not certain in any given case. These other species have, however, one advantage over the *simulans-melanogaster* comparison in that they have somewhat different chromosome groups. The chromosome groups of *simulans* and *melanogaster* are identical in appearance.

Dr. E. G. Anderson has studied a case in which two X-chromosomes, which carry different genes, are attached to each other. The offspring from such individuals indicate that the spindle-fiber is attached to the "right" end of the X, rather than to the left end as previously surmised. We have studied in this laboratory two other cases of attached X's of independent origin. In both cases it has been possible, owing to the occurrence of triploids, to introduce into one of the attached X's any desired mutant gene or combination of genes. In both cases many offspring have been obtained from females heterozygous for 7 genes, from scute (0.0+) or from yellow (0.0) to forked (56.8). These studies, when completed, should throw much light on the mechanism of crossing-over, and may require a reconsideration of the entire subject of coincidence.

Work in collaboration with Anderson on crossing-over in the X-chromosomes of 3n females has been completed and has furnished an independent method of proof that the attachment of the spindle fiber is at the "right" end

of the X. This conclusion was drawn from the fact that the so-called equational exceptions, produced by a 3n female, form a series of ascending frequency from zero for the genes at the right end to about 11 per cent of the total exceptions for the genes at the extreme left end. An equational exception is an individual that receives from the mother two X-chromosomes that are identical for some part of their length, while the mother had only one such chromosome. Identical parts are sister strands derived from an original chromosome by the equational split. Apparently the spindle fibers of sister strands always extend to opposite poles at the equational division, and hence for the genes at or near the spindle-fiber attachment no equational exception can arise. Since it is the genes of the "right" end that were observed not to give equationals it is the right end that has been identified as the point of spindle-fiber attachment. But if crossing-over occurs that involves one of the sister strands and a strand from another chromosome, then the spindle-fiber of this other chromosome can carry the distal end of one sister strand to the same pole as that to which the whole of the other sister strand is carried. In agreement with this hypothesis it is observed that one of the strands of each equational has always come from a crossing-over between one of the two sister strands and a strand from a different chromosome. The fact that the two chromosomes of equationals are identical for part of their length, but not for all, proves that the equational split occurred *before* the crossing-over, and that crossing-over occurs not in a 2-strand stage but in a 4-strand stage. Furthermore the crossing-over involves 2 only of the 4 strands at a given point of crossing-over.

In our last report it was stated that experiments showed that the reversions to wild-type, that occasionally occur in the stocks of bar eye, are due to crossing-over. It was suggested that such crossing-over is unequal, so that a female carrying bar in each X-chromosome may produce a few gametes with X's that carry no bar, and others with X's that carry two bars. Thus:

$$\frac{M \quad B \quad N}{M' \quad B' \quad N'} \text{ gives } M'N \text{ and } MBB'N'$$

The former is a "reversion" to round eye, the latter is the type called "ultra-bar" by Zeleny. Further work has fully confirmed this unequal crossing-over hypothesis.

A new and less extreme allelomorph of bar, called "infrabar" (B^i), has been found. This type also reverts to round and gives a form, called "double-infrabar" (B^iB^i), that corresponds to Zeleny's ultra-bar (now known as "double-bar"). Females that carry bar in one X and infrabar in the other X produce two new double types—"bar-infrabar" (BB^i) and "infrabar-bar" (B^iB). All the events just mentioned are accompanied by crossing-over at or near the bar locus.

Females that carry bar-infrabar or infrabar-bar in one X and round in the other X give rise both to bar and to infrabar, these events again occurring only with crossing-over. These last crosses furnish crucial evidence in favor of the hypothesis of unequal crossing-over, for analysis of the data shows that in these double types the component elements (bar and infrabar) maintain their identity, and also maintain their relative sequence in the same linear series as the rest of the genes. Only in sequence do bar-infrabar and infrabar-bar differ from each other.

While these results furnish an explanation for the origin of reversion and of double types in bar and infrabar stocks, there is abundant evidence that the explanation can not be generalized so as to make it apply to most gene mutations.

In our last report it was suggested that, on the above hypothesis, double-bar heterozygous for round should have the same number of facets as homozygous bar. Careful tests have shown that such is not the case; double-bar over round is only about two-thirds as large as homozygous bar. Furthermore infrabar-bar over round is two-thirds as large as bar over infrabar, and double-infrabar over round is two-thirds as large as homozygous infrabar. The conclusion seems inescapable that *two bar allelomorphs in the same chromosome are more effective in reducing facet-number than are the same two allelomorphs in opposite chromosomes*.

Among the numerous new mutants of *D. melanogaster* are two allelomorphs of rudimentary, one of which has females that are fairly fertile with rudimentary males, and the other (rudimentary¹²) is practically normal in its fertility. This last form is also of normal viability, and makes the rudimentary locus available in many kinds of experiments for which the former rudimentary mutations could not be used, because of their female-sterility and low viability. There are two other cases of multiple allelomorphs, one form of which is female-sterile and the other female-fertile (reduced bristles, female-sterile, and its allelomorph, scraggly bristles, which is fertile; and singed, which is female-sterile, while singed² and singed³ are fully fertile).

Several new Minutes have arisen, one of which (Mn) is located between Bar and bobbed in the right end of the X, and fills a breach in the map left by the loss through sterility of the mutant cleft. Mn, Mo, and Mk are all sex-linked characters that are dominant in the female and lethal in the male, and are very probably deficiencies, similar to the Notches. One Minute (Minute-l), located in the neighborhood of plexus in the second chromosome, was found to be a deficiency for plexus and also for arc, which lies about a unit to the left of plexus. This definite case greatly strengthens the supposition that the Minutes are generally deficiencies. Some of the other new Minutes (Mm, Mp, Mq, Mr,) are located where they would be useful in linkage work, but they are rather unreliable because of high sterility, somewhat low viability, and the uncertainty, in case they are deficiencies, as to whether crossing-over is affected. A very easily separable light pink eye-color promises to be a useful mutant in the second chromosome. The very excellent third-chromosome dominant Stubble has been more accurately located three-tenths of a unit to the left of spineless. The gap between pink and spineless, which has been an obstacle for many years, is filled by a suppressor of Hairy-wing (probably a piece of the X-chromosome translocated to the third) which is located at 54.8. Stubble and curled also lie in this region, curled at two units to the right of pink, or at 50.0. Several determinations of the distances between loci that are so close together that they are used interchangeably in experiments have been made. Thus, bifid and ruby are relocated 0.6 unit apart; tan and lozenge 0.2 unit apart; miniature and dusky 0.1 unit apart, and forked and bar 0.2 unit apart. The data of Mohr relocate Abnormal at 4.5 instead of at 3±.

A great deal of new information as to the relations between map-distances and corresponding percentages of recombination of the linked characters

has been accumulated by specific experiments upon all three major chromosomes. Thus, over 15,000 back-cross flies were raised from mothers heterozygous for Xple but with the mutants alternated to reduce viability disturbances

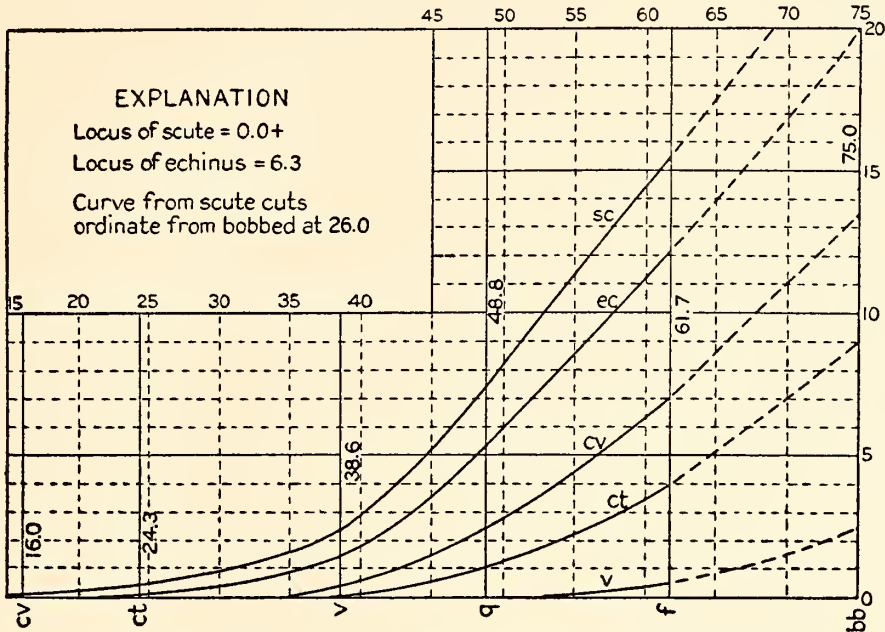


FIG. 1.—Curves showing difference between map-distance and percentage of recombination for the characters of the alternated Xple backcrosses.

to a minimum. $\left(\frac{sc}{ec} \frac{cv}{ct^6} \frac{v}{g^2} \right)$. These data form a valuable control for the many experiments in which alternated Xple is used. The curves showing the relation between the specific map-distances and the specific recombination percentages that obtain for these data are given in figure 1. More general curves based on standard data are being published in the *Drosophila* monograph which will be referred to later.

In the course of the last 14 years during which genetic work on *Drosophila* has been continuously in progress an extensive literature (about 300 papers) has accumulated. These papers are widely scattered and no consistent attempt to assemble all the results has hitherto been made. A year ago Dr. Kooiman asked us to bring together the work on *Drosophila* to be published as one of a series of monographs under the editorship of Professor J. P. Lotsy. We have completed this review and have added the necessary information in order to bring the subject up to date. Many of the mutant types referred to in special papers had not been adequately described. These, as well as other new types amounting to about 100 in all, have been described and many of them are figured in this monograph. A much more complete discussion of non-disjunction than that published in separate papers appears here. Non-disjunction of chromosome-IV, with the production of haplo-IV and triplo-IV types, is correlated with the general phenomena produced by deficiency and by duplication of chromosomal materials. The various cases of sectional-deficiencies, sectional-duplications, and translocations are analyzed as to their bearing on the way in which genes cooperate to produce a given effect.

The maps are brought up to date, and new information with respect to the relation between map-distance and the amount of recombination of linked characters is given. The literature list, which is as complete as possible, a full index, and the references in the text to the original sources will make it possible to find out what has been done on *Drosophila*.

Some of the experiments reported as in progress in former reports have been brought to completion and the results are now ready for publication. The selection of eyeless stock has been carried to the sixtieth generation. This material appears now to be homozygous in its genes, and since the condition of the eyes is still highly variable in response to environmental effects, it is suitable material for testing the hypothesis of the inheritance of acquired characters. The results show that the environmentally induced changes are not inherited.

Certain stocks with attached X-chromosomes continue to produce high male ratios. The evidence indicates clearly that the result is due to the death of half or more than half of the daughters, but as yet it has not been possible to locate the lethal or semi-lethal factor that produces this result.

The evidence is now complete that mutations occur that change the effects produced by other recessive mutant genes to the extent that the individual comes to resemble the wild type.

Several experiments are under way, the object of which is to determine whether extreme environmental changes may affect the germinal material in such a way that later generations inherit any defects that may be induced.

BOTANY.

Livingston, Burton E., Johns Hopkins University, Baltimore, Maryland.
The water relations of plants, with special reference to root absorption and transpiration as influenced by sunshine. (For previous reports see Year Book No. 22.)

During the past year several considerable improvements have been made in methods for the quantitative study of plant water-relations and new results have been secured, which are being incorporated with those previously available. Mr. J. D. Wilson, of the Johns Hopkins University, has continued as research assistant in this work.

Our recent inability to secure suitable black porous-porcelain spheres for use in estimating the effect of solar radiation on evaporation (with the Livingston radio-atmometer), has led to much further experimentation on spheres that are superficially blackened in various ways. Several new methods by which an experimenter may blacken the regular white spheres have been worked out. One of these employs a thin coating of collodion carrying suspended lampblack, and another employs a similar coating of agar gel. The collodion-coated pieces operate very well indeed and the agar-coated ones are nearly as good. In both cases the material must not be allowed to dry. After dipping in the collodion mixture the blackened spheres are placed under water and are so preserved when not in use. While in operation the exterior colloid layer is kept saturated with water from within, evaporation occurring from its outer surface. Neither of these blackened spheres loses its coating when rain occurs (which can not be said of the lampblack-coated spheres that have been used for the last few years), and both bear considerable rubbing when the exposed surface becomes dirty and requires cleaning. The collodion treatment is somewhat better than the other in this respect.

As this is being written we have just received what appear to be very satisfactory blackened spheres from a pottery and it is hoped that this phase of our studies may now be brought to a satisfactory stage for publication. The new blackened spheres are covered with a thin black layer of porous ceramic material, which is as resistant as the white porous porcelain itself. One of the chief difficulties in the past, in the study of sunshine influence on evaporation, has thus been at length overcome. The new, resistant, standardized, blackened spheres are now being employed in our transpiration studies. They promise to be perfectly satisfactory for the study of sunshine as a heating and drying influence, and should be very valuable in radio-atmometers used as self-integrating instruments in climatic investigations, especially in the hands of ecological workers in forestry, horticulture, and agronomy.

A new thermographic method for recording the heating influence of sunshine has recently been brought to actual test. It employs two Frieze soil thermographs with cylindrical bulbs, one nickeled and the other blackened. The record shows the difference between the temperatures of the two bulbs at all times, the blackened bulb being more or less warmer than the nickeled one during periods of sunshine. For ecological studies this device appears to be far more satisfactory than any other simple thermographic sunshine recorder; it shows not only what periods of the day are sunny, but also indi-

cates differences between the various degrees of sunshine intensity encountered throughout the day.

A new potometer method for handling uninjured plants in studies on absorption of water by roots has been perfected. The plants are grown with their root systems in a sealed reservoir of aqueous solution, to which the potometer tube is attached. Very small increments of water intake by the roots can now be readily measured volumetrically, with relatively great precision, and the influence of radiation, wind, etc., as well as that of the solution used about the roots, is now capable of satisfactory quantitative study. The new potometers are applicable only for plant forms that thrive with their roots in aqueous solution. This method has been used with willow (*Salix*) and buttonbush (*Cephalanthus*) in our experiments during 1924.

Osterhout, W. J. V., Harvard University, Cambridge, Massachusetts. *Continuation of investigations on permeability in cells.* (For previous report see Year Book No. 22.)

During the past year the work on *Nitella* has been continued in several directions. The penetration of a variety of substances has been studied and an attempt has been made to develop quantitative microchemical methods for the detection of penetrating substances. This is an important task, since the study of permeability depends on the development of such methods, and they will likewise be valuable in other investigations in cellular physiology.

At the same time an attempt has been made to extract sap, without contamination or alteration, in quantities sufficient for ordinary chemical analysis. It was found that two species of *Nitella* (one from Woods Hole and one from Cambridge) agreed in having approximately equal amounts of Na and K, in molar proportions, in solution in the sap. In this respect they differ greatly from the marine alga, *Valonia macrophysa*, in the sap of which K is more than five times as abundant as Na. The relation between Na and K in the sap of living cells is a question of great importance which deserves further study.

The sap of *Nitella* differs from that of *Valonia* in another important respect, in that it contains SO_4 , while that of *Valonia* does not. The fact that protoplasm is permeable to SO_4 in some cases and impermeable in others is of interest.

The effect of a variety of substances on penetration, as well as on exosmosis, has been studied. It seems to be possible, by means of certain reagents, to produce an increase in permeability and a partial exosmosis of substances which do not normally diffuse out of the cell. If this does not go too far the cell is able to recover its normal permeability when returned to its usual environment. This has an important bearing on theories of injury and recovery.

Studies have also been made of the electrical conductivity of *Nitella* as affected by a variety of conditions.

CHEMISTRY.

Noyes, Arthur A., California Institute of Technology, Pasadena, California.
Researches upon (1) the properties of solutions in relation to the ionic theory; (2) free energies and reduction-potentials; (3) a system of qualitative analysis including the rare elements; (4) the structure of crystalline substances determined by X-rays; (5) rates of chemical reactions; (6) the mechanism of contact catalysis. (For previous reports see Year Books Nos. 2-22.)

1. PROPERTIES OF SOLUTIONS IN RELATION TO THE IONIC THEORY.

During the past year two articles have been published by A. A. Noyes relating to the important theory of Milner and of Debye and Hückel, which accounts for the much discussed deviations of largely ionized substances from the behavior of perfect solutes by evaluating the energy effect due to the electrical attraction between the positive and negative ions. The first of these articles is devoted to a critical mathematical presentation of the theory, which is simpler in form than that given by the original authors, and which includes certain new supplementary derivations. In the second article the conformity of the theory with the facts is fully tested with the aid of the ion-activity values previously derived by Lewis and Randall, and with the aid of the available solubility-effect data. This testing led to the conclusions that, though separate substances show considerable variations from the requirements of the theory, yet, taking the experimental results as a whole, they conform strikingly to the predicted functional relations to concentration and valence of the ions; and they show that the average value of the empirical constant involved in these relations does not differ more from the theoretical than might arise from the uncertainty in the evaluation of the latter.

2. FREE ENERGIES AND REDUCTION POTENTIALS.

By measuring the electromotive forces at 25° and 45° of the voltaic cells: $\text{As(s)} + \text{As}_2\text{O}_3(\text{s}), \text{HClO}_4(0.2-0.9 \text{ n.}), \text{H}_2(\text{g})$, and $\text{Te(s)} + \text{TeO}_2(\text{s}), \text{HClO}_4(0.1-0.7 \text{ n.}), \text{H}_2(\text{g})$, Dr. Reinhardt Schumann has determined the free energies and heat-contents of arsenic trioxide and of tellurium dioxide. The free energies at 25° were found to be -137,300 cal. for 1 As_2O_3 (octahedral), and -64,320 cal. for 1 TeO_2 (solid).

The solubilities at 25° of these two oxides in perchloric acid solutions of concentrations between 0.1 and 0.9 normal were determined. The solubility of arsenic trioxide was found to decrease only a few per cent with increasing acid concentration; that of tellurium dioxide was found to be nearly proportional to the hydrogen-ion activity, indicating that the tellurium exists in acid solution in the form of $\text{Te}(\text{OH})_3^+$. With the aid of the solubility data the molal reduction-potentials for the reactions $\text{As(s)} + 2\text{H}_2\text{O(l)} + 3\oplus = \text{HAsO}_2 + 3\text{H}^+$, and $\text{Te(s)} + 3\text{H}_2\text{O(l)} + 4\oplus = \text{Te}(\text{OH})_3^+ + 3\text{H}^+$ were calculated to be -0.2375 volt, and -0.5590 volt, respectively. The work on arsenic has already been published.

A research has been carried out and published by Dr. R. M. Badger on the equilibrium of the reaction between ammonia gas and carbon, yielding the gaseous products hydrogen cyanide and hydrogen. Mixtures of ammonia and hydrogen cyanide, diluted with nitrogen, were passed over a layer of charcoal at 500°; and the issuing gases were submitted to a process of

analysis which was worked out after long experimentation. Since both ammonia and hydrogen cyanide would be almost completely dissociated at that temperature if equilibrium were attained, the desired equilibrium is a meta-stable one; but its study was made possible by the very slow rates of decomposition of these gases. A series of experiments in which equilibrium was approached from both directions yielded fairly concordant equilibrium-constants. With the use of the known free energy of ammonia the free energy of hydrogen cyanide gas was found to be 28,400 cal. at 800° (abs.) and 29,700 cal. at 298° (abs.).

3. SYSTEM OF QUALITATIVE ANALYSIS INCLUDING THE RARE ELEMENTS.

The experimental work on the system of qualitative analysis including the rare elements has been continued with the assistance of Mr. R. H. Dalton. The plan of separation of the elements precipitated by hydrogen sulfide has been fully worked out. Especial attention has been given to devising the best methods of analyzing for the troublesome platinum elements (platinum, palladium, iridium, rhodium, osmium, and ruthenium). With the exception of the alkali-group, the experimental researches on the whole system of analysis are now completed. Good progress has also been made during the past summer in preparing the material for publication.

4. THE STRUCTURE OF CRYSTALLINE SUBSTANCE DETERMINED BY X-RAYS.

The crystal structures of a number of benzene derivatives have been investigated by Dr. Maurice L. Huggins, with the object of determining the relative positions of the atoms in the benzene ring. The positions of the centers of the molecules in quinol and in tribenzylammonium chloride have been determined. A graphical method has been developed for the treatment of rotating crystal spectra. The structure of the tetragonal modification of mercuric iodide, HgI_2 , has been determined by Dr. Huggins and Mr. Paul L. Magill.

A powder photographic apparatus has been constructed by Mr. Linus Pauling for investigating the nature of solid solutions. Incidentally, in the development of this technique, the crystal structures of thallos chlorides and bromide were determined; these crystals being found to have the same atomic arrangement as cesium chloride. Mr. Pauling has also determined the crystal structures of the cubic crystals $(\text{NH}_4)_3\text{FeF}_6$ and $(\text{NH}_4)_3\text{MoO}_3\text{F}_3$. The results with the latter substance are noteworthy in that they indicate an arrangement in which fluorine and oxygen atoms are in equivalent positions. A determination of the space-group symmetry and arrangement of the uranium atoms in uranyl nitrate hexahydrate, $\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, has been published by Dr. R. G. Dickinson and Mr. Pauling. Dr. Dickinson has examined Laue photographs of metallic magnesium and has found the structure, in agreement with previous powder photographic work, to be hexagonal close-packing, or a close approximation to this arrangement.

5. RATES OF CHEMICAL REACTIONS.

In accordance with the program described in last year's report, experimental and theoretical work on reaction velocities has been continued, under the general direction of Professor Tolman.

Mr. E. C. White has continued his work on the initial rate of decomposition of gaseous nitrogen pentoxide. He finds the reaction to be of the first order, even when the partial pressure of the nitrogen dioxide produced is less than

0.5 mm. This confirmation of the order of the reaction is of interest, owing to the theoretical significance of such reactions. Mr. Oliver R. Wulf has carried out extensive experiments on the bromination of cinnamic acid, in the hope that this would be a suitable reaction for testing the relation between thermal and photochemical rates. It has been found too unreliable, however, and the decomposition of ozone is now being studied instead. Mr. Arnold O. Beckman has found that the bromination of dichlorethylene or of tetrachlorethylene also does not give reproducible rates.

A method has been found by Professor Tolman for calculating the mean life of activated molecules from data on the intensity of the absorption lines corresponding to the quantum jump by which the molecule goes from the normal to the activated state. An abstract of the work has already been published, and the full article will appear shortly. The work is a contribution to the interpretation of the rate of chemical reactions, since it is probable that molecules, in order to react, must be in an activated or higher quantum state.

6. THE MECHANISM OF CONTACT CATALYSIS.

A study has been made by Dr. A. F. Benton and Mr. P. H. Emmett of the rate of reduction of the oxides of nickel and iron by hydrogen, and of the behavior of these oxides and the corresponding metals as catalysts for the formation of water-vapor from mixtures of hydrogen and oxygen. This investigation has for its object the accumulation of data suitable for testing the theory of simultaneous oxidation and reduction in these catalytic reactions, and thus contributing to the knowledge of typical heterogeneous reactions. The work is ready for publication.

An investigation has also been undertaken by Dr. Benton to determine quantitatively the extent to which the absorption of hydrogen by platinum black is diminished by the presence on the surface of known amounts of various poisons. It is expected to use the experiments to test the hypothesis of unimolecular adsorbed films. In case this hypothesis is confirmed, they will furnish the basis for a method for determining the effective surface area of a finely divided solid.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts.
Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds. (For previous reports see Year Books Nos. 2-22.)

The following investigations have been in progress during the academic year, some of them continuations of work begun a year or more ago.

1. LEAD ISOTOPES AND THE ATOMIC WEIGHT OF LEAD.

With the assistance of Lawrence P. Hall the very carefully prepared fractions of ordinary lead separated by Harold S. King were analyzed with great care. Each was adequately purified and distilled in quartz tubes. Each fraction gave, within the limit of error, the same atomic weight, namely, 207.216. It is evident then that neither the Grignard process nor distillation in a very high vacuum was adequate to effect separation of ordinary lead into isotopes. The analysis of similar fractions prepared from radioactive lead is almost completed.

2. THE HEAT OF REACTION OF VERY SLOW CHEMICAL PROCESSES.

Mr. Oscar C. Bridgeman, as previously reported, had studied the heat of hydrolysis of various esters by means of a new and elaborate apparatus. Mr. Hans C. Duus has made improvements and simplifications in the apparatus and found it to be extraordinarily efficient. With it he has investigated another type of slow reaction, namely the esterification of the various alcohols. His results are consistent and evidently of great value. They are almost ready for publication.

3. THE HEAT OF COMBUSTION OF CARBON COMPOUNDS.

Mr. Stewart S. Kurtz jr., having improved the apparatus for determining heats of combustion, has begun the actual work upon this subject. He has not yet had time to obtain the series of results concerning related compounds, which are the object of this research. Mr. Kurtz proposes to continue the work during the academic year, 1924-25. In the light of the experience and knowledge of the subject he has obtained, there is hope for valuable results.

4. HEATS OF NEUTRALIZATION AND HEATS OF DILUTION.

Mr. Frank T. Gucker jr. has devised and set up, with help from this Grant, an apparatus for determining the specific heats of solution which is apparently the best devised. With it he has already obtained final results for the specific heats of a large number of frequently used solutions. The experimental work on this subject has been finished and will be published as soon as possible. It is hoped that next year Mr. Gucker may go on with thermochemical work of this kind, studying the heats of neutralization of organic acids, of which he has just determined the specific heats.

5. THE OXYGEN ELECTRODE.

Mr. William T. Richards has spent a number of months on the study of the oxygen electrode in order to determine the extent of its usefulness and to solve its puzzling theoretical aspects. He has obtained much new light on the subject and has devised a method by which, in spite of its irregularities, the oxygen electrode may serve as a useful guide to the degree of alkalinity of salts. Moreover the results throw new light on the mechanism of this electrode and provide the basis for a more adequate theory of its irregular working.

6. THE SEDIMENTATION OF VOLUMINOUS PRECIPITATES.

Mr. William T. Richards has made an experimental study of the rate of settling of various bulky precipitates, such as aluminum hydroxide. He has been enabled to separate or to identify the several effects of gravitation, viscosity, cohesion, etc., which govern this rate of settling. This study ought to have practical as well as theoretical interest.

7. A NEW COMPRESSIBILITY APPARATUS.

With the help of Mr. John C. Solberg of the Watertown Arsenal, Mr. William T. Richards devised a new form of apparatus for the determination of compressibility under high pressures. This apparatus was constructed through the kindness of the United States Government at the Watertown Arsenal, and has been thoroughly tested. It is now ready for use and should yield important data concerning the behavior of metals and other substances under high pressures.

Much time has been spent on the theoretical study of the existing data on the last-named subject and a new method for the computation of the internal pressures of metals has been suggested.

Seven papers concerning work which has been done with this Grant have been published during the last academic year. (See Bibliography.)

Sherman, H. C., Columbia University, New York, N. Y. *Chemical investigation of the amylases and related enzymes*. (For previous reports see Year Books Nos. 11-22).

The work of the year has been chiefly devoted to two main lines of investigation: (1) Continuation of the study of the optimum hydrogen-ion concentration for measurements of activity of the enzymes under different conditions of time and temperature, preliminary results of which were noted in the report of last year; (2) continuation of the electrophoresis experiments mentioned in our report of 1922, which have now resulted in the successful determination of a definite iso-electric point or zone for malt amylase, the first typical enzyme for which this important physico-chemical property has been determined.

In our studies of the chemical nature and enzymic activities of the amylases it has been shown that all experimental conditions must be carefully controlled, and especially that the optimum hydrogen-ion concentration for the activity of each enzyme must be adhered to, if quantitatively comparable data are to be obtained. In most of our work, enzymic activities have been measured in standard experimental periods of 30 minutes at 40° C. Recently, however, in connection with our studies of the protein nature of these enzymes by the indirect but very instructive method of observing the influence of different amino acids upon the activity and stability of the enzyme in its aqueous dispersions, we have had occasion to make use of variations in the times and temperatures of such experiments. It thus became necessary to carry out a long series of quantitative measurements of the enzymic action, separately for each of the amylases with which we are here concerned, in order to establish the hydrogen-ion concentrations (in terms of pH) which induce optimum activity under the various conditions of time and temperature. This work, as originally planned, has been completed during the past year; the data, however, reveal an interesting apparent difference between the two amylases which seems to call for further investigation. It is hoped that this phase of the research may be completed and published within the coming year and our final interpretation of the data be included in the next annual report.

Both from the standpoint of intrinsic theoretical interest and promise of important practical applications in the future research of our own and other laboratories, the outstanding feature of our work during the past year has been the successful demonstration of electrophoresis of malt amylase and the completion of a systematic series of electrophoresis experiments which establish the iso-electric point or zone of this typical enzyme. These experiments were undertaken in part as a direct study of the physico-chemical nature of malt amylase and in part as a possible means of further improvement in the methods which have been developed through the work begun by Dr. T. B. Osborne and continued in this laboratory for the purification of this enzyme. Since this work has repeatedly pointed to the protein nature of the enzyme, and since proteins are least soluble at their iso-electric points, it was thought

that separation of the enzyme from the inactive proteins with which it is mixed in crude extracts of malt might be facilitated by precipitation at the iso-electric point of the enzyme. Through the co-operation of Professor A. W. Thomas of the Department of Chemistry of Columbia University, and of Dr. M. L. Caldwell, formerly research assistant in these investigations and now instructor in Chemistry in the same Department, it has been possible to surmount the many difficulties involved and to develop an apparatus and experimental method, by means of which we have carried out large numbers of electrophoresis experiments with malt extracts and solutions of purified malt amylase adjusted to a wide range of hydrogen-ion concentrations by means of buffer solutions. The experiments with commercially concentrated malt extracts showed that, while there was some evidence of electrophoresis of the active substance, consistent results could not be obtained with the crude material. This is probably because of the presence in such extracts of relatively large amounts of inert proteins of varying iso-electric points which may have masked the electrophoresis of the enzyme. Entirely consistent evidence of electrophoresis was, however, obtained from experiments upon solutions of purified malt amylase which had been prepared in this laboratory by our modification of the Osborne method. It is evident from our experiments with two independent preparations of this enzyme that a migration of the active material takes place under the influence of the electric current and that the direction of this migration is definitely dependent upon the hydrogen-ion concentration of the enzyme solution. The two enzyme preparations have given similar results, and in each case the change in the direction of migration of the malt amylase occurs between pH 4.3 and pH 4.5. In solutions on the acid side of this narrow range the enzyme under the influence of the electric current moved toward the cathode (behaved as a cation) and in solutions on the alkaline side it moved toward the anode (behaved as an anion). These results thus definitely establish an iso-electric point or zone for this enzyme at pH 4.3 to 4.5. This adds evidence of a new kind for the belief that the enzyme is protein in its chemical nature. It also adds a new method for the investigation of the physico-chemical nature of enzymes and other unstable ampholytes.

It is of distinct theoretical interest to find that the iso-electric zone and the zone of optimum enzymic activity of malt amylase coincide, indicating that the enzyme exerts its optimum effect upon starch when it is in its least ionized and least hydrated condition. This may be interpreted as an indication that its attraction for the starch particles is greatest when its combination with water is least; in other words, that it is best adsorbed by starch when it is in its iso-electric (least hydrated) condition. This is in accord with the work of Abderhalden and Fodor, who found that the maximum adsorption of amino acids and proteins from aqueous solutions by charcoal takes place when the hydrogen-ion concentration of the solution is at the iso-electric point of the amino-acid or protein. Moreover, the addition of neutral salts, which they found to increase adsorption from solutions which were not at the iso-electric point of the solute (protein), we have found under analogous conditions to increase the enzymic activity of the malt amylase.

The results of this work upon the iso-electric point of malt amylase have been published in the *Journal of the American Chemical Society* for July 1924, and experiments are now being undertaken with a view to establishing, if possible, the iso-electric point of pancreatic amylase also.

Since the extreme instability of this latter enzyme may prove an insurmountable difficulty in electrophoresis experiments, we plan to study the problem of its iso-electric point by means of adsorption experiments as well, thus combining this phase of the work with a systematic investigation of the merits of the adsorption method as a possible step in the process of purifying the amylases. With the purification processes sufficiently interpreted and systematized, we hope that it may be possible within the coming year to undertake further studies of the kinetics of the action of these enzymes.

The efficient collaboration of those who have shared in the work of the past year, whether as research assistants or as volunteer associates, is gratefully acknowledged.

Smith, Edgar F., University of Pennsylvania, Philadelphia, Pennsylvania.
Continuation of the study of the sodium tungstates. (For previous reports see Year Books Nos. 16, 17, 22.)

In my continued study of the sodium tungstates, a very convenient and quite satisfactory method of separating the 4:10 and 5:12 salts was found. This led to the determination of a very definite procedure of producing the 5:12 salt. The examination followed of the 7 soluble sodium tungstates, the existence of 2 of which (the 1:2 and 1:3) had been problematical. The result showed that the 5:12, the 4:10, and 3:7 salts could be synthesized from the 1:1 and 1:4 salts. Doubt had existed as to whether the 3:7 salt was a true, independent member in the series of soluble sodium tungstates. The synthesis proved it to be so.

Further, it developed that hydrolysis of aqueous solutions of the 5:12, 4:10, and 3:7 salts occurred on boiling. This hydrolysis proved to be quantitative in character. In other words, the 5:12, 4:10, and 3:7 sodium tungstates were combinations of normal sodium tungstate (1:1) and sodium metatungstate (1:4). If the 5:12, 4:10, and 3:7 salts were melted, and the cold mass treated with water, the normal (1:1) salt in them dissolved out, leaving the insoluble fused 1:4 content. However, when efforts were made to synthesize the 1:2 salt and the 1:3 salt from the normal and meta-salts failure appeared, doubtless due to the fact that the expected bodies sustained hydrolysis with the formation of the 5:12 and 4:10 salts. Hence, of the 7 soluble sodium tungstates but 5 have been prepared from the union of the normal salt (1:1) with the meta-salt (1:4).

What would result on adding barium chloride to an aqueous solution of the 5:12 sodium salt? Experiments showed that if performed in the cold the resulting precipitated barium salt gave the ratio of basic oxide to acid oxide to be as 5:12. This was also true of the calcium, strontium, manganese, cadmium, and cobalt salts. From hot solutions, however, salts were obtained in which the ratio of basic oxide to acid oxide was as 3:7. Previous heating had occasioned the aqueous solution of the 5:12 salt to hydrolyze into 3:7.

The study occupied itself also with the search for reliable analytical methods. It was found that the exposure of anhydrous normal sodium tungstate to hot vapors of carbon tetrachloride led to a complete volatilization of the tungstic acid and formation of sodium chloride. Other derivatives behaved similarly; for example, the barium salt.

The investigation is being continued along several lines.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology*. (For previous reports see Year Books Nos. 16-22.)

The spring and summer throughout most of the West have been so exceptionally deficient in rainfall that several proposed field trips were abandoned and others were much shortened. On the botanical side these were limited to a brief journey through the Mohave Desert, one through northern California, Oregon, and Washington, and a third into northern Arizona and New Mexico. Two bio-ecological expeditions traversed the desert region of California, Arizona and New Mexico, and Colorado, and one of these returned through Wyoming, Utah, and Nevada.

The major activities of the year have been maintained at the Alpine and Desert Laboratories, in garden and herbarium at Berkeley, California, and in the competition fields and gardens at Lincoln, Nebraska. The various projects in experimental evolution have been carried forward in both the Petran and Sierran transects, while the prairie-plains series in experimental vegetation has been left inactive to demonstrate the cumulative effect of the climate upon the species established. The grazing stations in southern and northern Arizona have been maintained as usual and several new exclosures added. A new base has been established at Santa Barbara, California, and experiments initiated in experimental morphology and pollination.

The Water Cycle in Plants, by F. E. Clements and J. V. G. Loftfield.

The studies of the past year have dealt mostly with the echart and with wilting in annuals. The wilting point changes with the factors controlling evaporation and transpiration, since wilting has been found to occur at a lower echart when evaporation is low than when it is high. When the points at which wilting occurred under the different conditions of evaporation and holarid are plotted, it is found that at first the echart rises very slowly with considerable increases in evaporation, but much more rapidly as the latter becomes intense. When the transpiration of plants of *Typha* employed as phytometers rose to 200 gm. per hour per square decimeter, the mesophytes found it impossible to withstand wilting, even in heavily watered pots.

Studies of wilting were made in the garden at Santa Barbara with a number of garden species, such as *Celosia cristata*, *Campanula medium*, *Antirrhinum majus*, *Tagetes patula*, and *Datura arborea*, and with introduced weeds, *Amarantus retroflexus*, *Chenopodium album*, etc. These were maintained at a point slightly above the echart so that they wilted regularly and decisively at mid-day, but were fairly turgid for the remainder of the 24 hours. The relation of excessively rapid transpiration to wilting and a temporary echart was repeatedly demonstrated by watering or shading individual plants of the various species, recovery taking place in a half to 2 hours. The results likewise indicated that the effect was due to the failure of absorption to keep pace with transpiration and not to slow or defective conduction, the plants reviving quickly after watering, even at times when the factors controlling evaporation were still rising. One interesting corollary of this relation was seen in the behavior of snapdragons covered with rust and cockscombs infested with aphids. All such individuals wilted far more quickly

than healthy ones, recovered much more slowly, and became permanently wilted while uninfected plants and species were still growing normally.

Conduction experiments show that in mesquite (*Prosopis juliflora*), sucker shoots from irrigated trees give 2.2 times the rate of conduction found in shoots of similar size growing in a xerophytic habitat. The range of difference in *Parkinsonia microphylla* was not as great, being only 1.3. The difference between *P. microphylla* and the streamside species, *P. torreyana*, was somewhat greater, the ratio being 1 to 2.3. These results indicate that the amount of water available to the shoot determines the number and size of the conducting vessels. The patterns formed in cross-sections by the transport of dilute stains in cut shoots under manometer pressure have been utilized to determine whether water is conducted by the same vessels as under normal transport. It was thought that pressure might bring into commission vessels that do not ordinarily conduct water because of inadequate connection with the leaves. This proved not to be true, as the same vessels took the stain in the same manner in each case. In many stems, notably *Holodiscus dumosus*, *Jamesia americana*, *Physocarpus monogynus*, and *Acer glabrum*, the last layer of wood was found to conduct poorly or not at all, possibly owing to the exceptional season of drought.

Typha latifolia proved to have a unique system for absorption and conduction, since it was capable of replacing a water-loss of 200 gm. an hour per square decimeter of leaf surface. This rate was held for nearly 6 hours without producing signs of wilting, and probably could have been maintained more or less indefinitely. No other species of mesophyte or hydrophyte employed was able to withstand such severe conditions of evaporation.

Physical Properties of the Sap of Engelmann Spruce, by G. W. Goldsmith and J. H. C. Smith.

Studies of the physical properties of spruce sap were continued by the same methods and at the same stations as in 1923. The water-content of the leaves varied directly with the altitude of the stations during the winter period, due apparently to a lowered chresard caused by freezing. During the summer this relation does not hold, since the age of the new leaves is determined by the arrival of spring and is thus different at the various stations.

The average molecular weight of the solutes tends to rise in the young leaves as the season advances. During the spring and early summer the values are variable and show little recognizable relation to station or season. The osmotic pressure of the sap, computed by the depression of the freezing point, exhibits a negative correlation with the water-content of the sap and a positive correlation with the refractive index. The electrical conductivity of the sap is very variable and does not show a close correlation with any other curve. This is probably due to alterations in the organic as well as the inorganic solutes of the sap. The density seems to be a straight-line function of the water-content of the sap and since this value can readily be calculated from the refractive index, the use of the refractometer promises to afford a convenient and valuable measurement of transpiration activity.

The total sugars, carbohydrates, and tannins present in the leaf do not agree closely with values obtained in the study of the physical properties of the sap. Hence, it is difficult to determine the properties of the cell-sap from an analysis of the solution obtained from the entire mass of leaf tissue.

The initial acidities of the expressed sap as determined by the hydrogen electrode are extremely variable. Equilibrium is difficult to obtain, possibly due to oxidation changes going on in the sap during the determination. Electrometric determinations of the initial acidity of spruce sap must be carried out with extreme care to be of value. Titration curves are very instructive, since all the sap shows a high buffer action when titrated with alkali. The type of curve obtained indicates compounds that dissociate at various acidities, possibly salts of dibasic acids. Titration with HCl shows considerable buffer action and indicates compounds that dissociate, liberating hydroxyl ions, and producing a more alkaline solution with the addition of acid.

Experimental Pollination, by F. E. Clements and Frances Long.

The last two seasons have precluded further experimental studies at the Alpine Laboratory, since one was almost continuously cloudy and rainy and the other the driest on record. As a consequence, advantage has been taken of garden opportunities at Santa Barbara, California, to extend observational methods in connection with new lines of work. The garden most available contained cultivated and native species in about equal number and rendered it possible to make a comparative study of life-histories, competition, etc.

A new method of box transplants has been devised to facilitate tracing the details of life-histories and pollination behavior. It consists simply in transplanting one or more individuals of the desired species to suitable containers, taking pains to injure the roots as little as possible and to leave the plants in the shade for a day or two. Boxes of galvanized iron, a foot or two long and half as wide, with a bottom that can be slipped into place beneath the soil block, are perhaps most satisfactory, but wooden boxes and large flower pots have also been used to good effect. Such a method greatly promotes accuracy, convenience, and comfort, and enables one to work much more rapidly, but its outstanding value lies in the ease with which plants can be manipulated. It permits assembling them in one place for the minute study of life-histories, as well as combining them in pairs or groups of all sorts for the study of competition. They may be readily raised or lowered to modify the visibility in insect flowers or to vary the trajectory in wind-pollinated ones. Box transplants may be moved from one habitat or climax zone to another, transferred from sun to shade or the reverse, or exchanged between field and garden. The water-content of the box may be varied within wide extremes with striking results, and finally, the boxes may be shifted about in relation to the hives, nests, pathways, or distribution areas of the species of pollinators. Such boxes are indispensable to the quantitative study of pollination processes in which it is necessary to measure the production of pollen, the rate of removal, deposit, and the final effect in seed production.

The work with life-histories has been confined largely to wind-pollinated flowers, *Plantago lanceolata*, *Celosia cristata*, *Chenopodium album*, *Populus fremonti*, etc., and to ephemeral or hemeranthous ones, *Ipomæa purpurea*, *I. nil*, *Anagallis arvensis*, *Eschscholtzia californica*, *Godetia amæna*, etc. These were followed in minute detail, by paying visits more frequently than the round of changes required and especially by keeping box transplants close at hand so that movements could be recorded as they occurred. Not only were the life-histories rendered much more exact and complete by this method, but it

also permitted the discovery of movements and details previously unknown. Thus, in *Plantago* it was found that the opening of each flower and the uncoiling and exertion of the stamens was a continuous process, these changes taking place graphically in a few minutes. With *Ipomæa*, opening was much more gradual, beginning usually in the later part of the afternoon as the temperature dropped and the humidity rose, and lasting nearly to midnight, when the flowers were fully expanded. In both cases, opening could be hastened or retarded by manipulating the holard, and closing similarly modified.

The large number of humming-birds in the garden, as well as their behavior, indicates the existence of a keen competition between them. Although the so-called humming-bird flowers with long tubes and red color were abundant, e. g., *Bignonia*, *Lantana*, *Bougainvillea*, etc., tubular flowers of all hues were regularly visited, such as *Plumbago capensis*, *Antirrhinum majus*, *Campanula medium*, and *Delphinium ajacis*. Even the flowers of *Hoya carnosa*, which are disk-shaped and nearly white, are eagerly sought, in competition with *Apis*. The tube in *Bignonia radicans* is too deep for the species visiting it and these steal the nectar by puncturing the tube just above the edge of the calyx. In one situation hundreds of corollas were rifled shortly after they had opened. In the case of *Lantana camara*, humming-birds exhibited the same discrimination shown by bees, probing only the fresh yellow flowers of each cluster and ignoring the older orange ones.

Further Studies in Flower Movement, by G. W. Goldsmith and Lee Bonar.

The work on the opening and closing of flowers has been extended to include a large number of native and cultivated species. The normal behavior is studied in the field and the habitat factors determined immediately before and at the time of floral movements. A photographic record of this behavior is made, any variation occurring at the time of movement being noted and later checked experimentally. The effects of cutting and of various habitat factors have been followed by means of special apparatus. Temperature alterations are produced about the plant under experimentation by driving air through heated or cooled coils and into the bell-jar inclosing it. The light intensity is modified by the use of shade-tents of various densities, and the humidity by forcing air through a mixture of sulphuric acid and water. The temperature and humidity factors within the bell-jar are determined by inclosing a thermometer and dew-point apparatus with the plant and noting the changes from time to time, and the light values are measured by means of a stopwatch photometer.

The mechanism involved in the movement of flower parts is being studied: (1) by placing longi-sections of open or closed flowers or heads in solutions of known osmotic concentration and determining the resulting movement of the parts (either by degree of movement as measured by a protractor or by successive drawings with a camera lucida); (2) by immersion of sections in solutions of equal osmotic concentration at different temperatures to check the temperature effect on permeability; (3) by placing sections in solutions of equal osmotic concentration in order to check permeability to different substances; (4) by microscopic observation of sections placed in different solutions to determine plasmolysis and protoplasmic movement; (5) by supplying the cut stems with water under various positive and negative pressures;

(6) by a determination of the sap-content of the flower or of the active tissues at various stages of opening or closing; (7) by measuring the transpiration of the flower when open and closed.

Tulips open in the morning and close in the evening, usually repeating the movement for several days, the number depending on weather conditions. In hot, dry weather, this is one or two days, while during cool, moist periods flowers often remain active for five days. Cutting produces no change in behavior. Moderate heating opens closed flowers, while cooling causes closure. Open flowers close when exposed to conditions favorable to a high evaporation rate, though at moderate temperatures humidity seems to have little effect. Flowers remain open at high temperatures when the humidity is high, but close at the same temperatures when the humidity is low. Longi-sections of the flower placed in distilled water at 20° go through a movement similar to that of closing. Immersion in molar sucrose solution causes an opening movement. It is probable that opening and closing are produced by turgor changes in the tissue at the base of the perianth and that these are normally caused by changes in permeability of the cells.

Heads of *Taraxacum officinale*, *Tragopogon pratensis*, *T. porrifolius*, and *Aster bigelovi* behave in much the same manner as the tulip flower. In each case the heads open with rising temperatures in the morning and close in response to excessive evaporation or falling temperature. During the early summer, flowers of *Taraxacum* seldom encounter excessive evaporation and hence remain open throughout the day, but later in the season unprotected heads close by 10 a. m. *Aster bigelovi* remains open during most of the day, while flowers of *Tragopogon*, blooming in midsummer on the open plains, close by 10 a. m. Heads of *Taraxacum* and *Tragopogon*, exposed to similar conditions, respond in approximately the same time.

The ephemeral flowers of *Linum perenne*, *L. grandiflorum*, *L. usitatissimum*, *Convolvulus arvensis*, *C. sepium*, *Anogra albicaulis*, *A. coronopifolia*, *A. pallida*, *Onagra lamarckiana*, and *Tradescantia virginiana* open when the temperature is lowered, but those of *Hibiscus trionum* blossom as it rises. Closing or collapse is a consequence of excessive transpiration in response to high temperature and decreasing humidity. *Mentzelia nuda* and *M. multiflora* usually open during the early evening and close by 9 p. m. They are apparently very sensitive to temperature changes of small range and hence their behavior was very puzzling at first. Flowers of the latter can be opened by a fall in temperature of 2°, but will remain closed if the decrease is much in excess of this. When opened by lowering the temperature, a further decrease produces closing.

Turgor changes in the tissue at the base of the moving parts are probably responsible for the opening and closing movements of the flowers studied. These turgor changes are induced either by the transpiration of the flower or by alterations in the permeability of the active tissue resulting from temperature changes.

Competition and Correlation in the Plant Body, by F. E. Clements.

The study of the competition between the different organs and parts of the plant body and their correlated development has been organized on a comprehensive basis and new methods devised. The major emphasis still rests upon buds, though flowers, flower parts, and fruits have received preliminary

attention. The background for the experiments has been furnished by extensive observations of buds and flowers under normal and abnormal conditions in a score or more of species. The experimental methods have been concerned chiefly with changes in position of all sorts, removal of one or more parts in varying number and under various conditions, girdling, wounding, and compression, the insertion of buds or other parts, and the addition of physiologically active substances, such as water, sugars, nutrients, salts, acids, etc. The experiments have also been combined in diverse fashion in order to furnish checks upon each other and have been repeated in different seasons and years for the same purpose, as well as to exhibit the range of behavior. An endeavor has likewise been made to follow the storage cycle in close detail, to discover its precise relation to growth, and to determine the variations in it from season to season.

Observations on erect, horizontal, and hanging twigs of *Populus* and *Prunus* agreed with those of the three preceding years to the effect that tip buds developed first regardless of position, and this was confirmed by the behavior of shoots purposely inverted. In the cottonwood, leaf and flower buds, both staminate and pistillate, behaved alike, the tip buds of hanging shoots starting first in 99 per cent of all cases. Removing buds from the tip downward regularly forced the next buds into growth, as did the removal of part or all of the last three seasons' growth in *Melia*, but the excision of intermediate buds was without apparent effect. Notching twigs on both sides above or below buds was ineffective, but constriction due to wire bands led to development in 2 to 4 buds immediately below, while the same buds on check shoots remained suppressed. Stripping portions of the bark and wounding in other ways also produced growth, usually below and more rarely above the injury.

In feeding glucose to suppressed buds, series of four adjacent ones were employed: a tube with 1 per cent glucose was inserted above one bud and below a second, a tube with water above or below the third bud, and a gimlet wound made in the vicinity of the fourth, the wound being filled with moist cotton and wrapped with tape to prevent drying. The buds responded to glucose in every case, whether inserted above or below, and in most cases to water alone, but not to wounding. Water had failed to produce a response the year previous, and the positive result was probably due to the much more advanced condition of the twigs. In similar groups of four, glucose and sucrose yielded almost identical results, the growth varying somewhat with insertion above or below the bud.

In the experiments with flowers, the holarid or light intensity was modified within wide extremes, producing a direct effect in the shoot and a correlated one in the inflorescence, flowers and heads were modified by the excision of various parts, and the different organs and parts were subjected to the action of various solutions injected by means of a Luer tuberculin syringe. In many cases these produced striking effects. With *Campanula medium*, allowing the plants to wilt and dry for 3 weeks after blooming and then watering abundantly threw suppressed flower buds into vigorous growth and resulted in doubling the corolla, 4 to 5 additional tubes developing outside the usual one. Induced drought in box transplants of *Plantago lanceolata* led to the partial suppression of some of the upper flowers, the corolla opening incompletely and the anthers remaining in the tube instead of being exerted on long filaments.

The Nature and Rôle of Competition.

FIELD AND NATURAL CULTURES, BY F. E. CLEMENTS AND J. E. WEAVER.

Competition, probably the most important function of the plant community, has long remained the one least investigated. In fact, no comprehensive and thorough analysis of it has previously been attempted, with the exception of the series of control cultures carried out from 1903 to 1905, the results of which have never been published (Clements, 1905:305, 1907:251; cf. Clements and Weaver, *Experimental Vegetation*, 1924). In the present researches, the endeavor is made to organize and prosecute the work in an exhaustive fashion, with respect to the factors in control, the functions and structures affected, the rôle of competition in succession and climax, and the part it plays in the origin of new forms. The attack upon this group of problems is almost exclusively experimental and is being conducted by means of simultaneous experiments in greenhouse, garden and field, and in the native communities. The several culture stations are located in the prairies, chaparral, and swamps at Lincoln, Nebraska; in grassland, chaparral, and forest at Weeping Water, 35 miles eastward; and in various cultivated fields.

FIELD CULTURES.

Seeding.—For the analysis of competition between prairie dominants and subdominants, seeds of paired selected species were planted in the greenhouse in flats 14 inches square and 6 inches deep, with removable bottoms. When the seedlings were 1 to 4 inches high and of even stand, the contents of the flat were transplanted into the prairie. A strap-iron frame, 14 inches square with the central portion divided by cords at right angles into 100 inch squares, was fastened in place by wire stakes. This outlined permanent areas in which the individual plants were counted three or four times during the growing season, and permitted an accurate record of growth, tillering, dominance, suppression, and mortality. About 60 of these areas were studied on low and high prairie. In addition, duplicate or triplicate plats of each species or mixture were grown in prairie or cultivated area in order to determine the rate of growth without competition and to study the root habits and relations.

Species were arranged in cultures as follows: (1) dominant competing with dominant, e. g., *Andropogon furcatus* with *Panicum virgatum* on low and *A. scoparius* with *Stipa spartea* on high prairie; (2) climax species with relicts, e. g., *A. nutans* with *Sporobolus asper*; (3) tall-grasses with short-grasses, e. g., *Agropyrum glaucum* with *Bulbilis dactyloides*; (4) dominant with subdominant, e. g., *Andropogon nutans* with *Onagra biennis*; (5) subdominant with subdominant, e. g., *Liatris punctata* with *Kuhnia glutinosa* and (6) dominant with ruderal, e. g., *A. scoparius* with *Amarantus retroflexus*. Water-content and light were determined from time to time and continuous records were kept of humidity, temperature, and evaporation. Bisepts were employed to exhibit the shoot and root relations, and with the factor readings revealed the course of events and the causes of the dominance, suppression, or disappearance of the different species. Photographs at the times of quadrating made the record complete. By the middle of the summer, the value and accuracy of the methods had become evident and illuminating results were being obtained in regard to association and succession.

Transplants and Disturbed Areas.—The competition between the grass dominants is also being determined by transplanting undisturbed sods

of 0.25, 0.5, and 1 square meter into the midst of other competitors. The smaller sods of *Bulbilis dactyloides* and *Bouteloua gracilis* transferred to low prairie are already suffering from the shade of the taller grasses, as is also *Agropyrum glaucum* to a less degree, but all the larger ones are flourishing. Reciprocal transplants of large blocks of rhizomes of *Scirpus lacustris*, *Typha latifolia*, and *Phragmites communis* have been made in pure growths of each community respectively, and the behavior followed. The effect of partial or complete removal of competition upon the growth, anthesis, and seed production of various species is also being determined. In mixed areas of tall and short grasses, the development of each type is being studied after the removal of the other by repeated cutting just below the soil surface. Even in a season of good rainfall, marked differences were found. In other quadrats, all but one or two dominants have been removed, and in still others everything except one or more of the subdominants. Certain areas are modified by watering or shading in the endeavor to disclose the respective rôles of the different physical factors.

Natural Vegetation.—The analysis of the competition between grasses and grasses, shrubs and grasses, trees and grasses, or trees and shrubs lends itself readily to experimentation in natural communities. Overgrazed areas where *Bulbilis* is competing with *Agropyrum* and other tall-grasses, and *Symphoricarpos vulgaris* with each of these, have been fenced, the ecotones marked and typical areas quadrated. Other areas where *Rhus glabra* is invading both high and low prairie have been similarly studied, the mode of invasion both above and below ground being determined and the critical factors measured. At Weeping Water further studies are being made and the competition between various prairie species and *Corylus americana* and between the latter and oak forest followed in detail. The natural ecesis of oak seedlings in grassland and chaparral is being recorded, while maple, elm, box-elder, linden, and other tree seeds have been planted in grassland, chaparral, and forest at the several stations. Of especial interest is the growth of shrubs and trees in grassland under various degrees of competition. Rhizomes of *Symphoricarpos*, *Rhus*, and *Corylus*, and seeds of *Fraxinus*, *Acer negundo*, *A. saccharinum*, *Gleditsia*, and *Ulmus* were planted in small parallel trenches. One lot of each was unaided, another was watered, the vegetation was kept clipped about the third, while the soil was denuded for a foot on each side of the others. Marked differences in growth occurred, the light being so low in the first and second groups as to cause the plants to become greatly attenuated; growth was poor in the clipped row, but excellent where the competition was less severe.

CROP AND CONTROL CULTURES, BY J. E. WEAVER AND H. C. HANSON.

CROP CULTURES.

Wheat.—Marquis spring wheat was planted in similar tenth-acre plots at the normal rate for eastern Nebraska (75 lbs. per acre), and at half, twice, and four times this rate. As the crop developed, extensive measurements were made of height, diameter of stem, number, length, width, and structure of leaves, degree of tillering, total leaf-area, photosynthetic area, number of roots, their extent and dry weight, etc., in addition to readings of the water and nitrate contents, of light, and humidity. The cold, wet spring delayed nitrogen fixation, and hence the nitrates were used as rapidly as available, resulting in etiolation in the dense cultures. During the drier part of the season the soil showed a progressive lower holdard in the denser plots, where the light was also

correspondingly less. On May 11, 12 plants in the 0.5 N plot yielded 0.375 gm. of roots (dry weight) in the surface cubic foot, while 108 plants in the 4 N plot gave 1.775 gm.

Owing to competition for light, stem height was greatest in the 4 N plot and least in the 0.5 N at first, but by June 1 the order was reversed. By June 9 the relative development was as follows (table 1).

TABLE 1.

Measurements.	0.5N	N	2N	4N
Average height (in.).....	18	18	17	15
Diameter of stem (mm.).....	3.5	3.0	2.6	1.9
Length of fifth leaf (cm.).....	18.2	14.9	12.8	8.8
Width of fifth leaf (mm.).....	11.7	10.0	8.6	6.1
Average No. tillers.....	9.2	4.1	1.6	0.6
Percentage of dead tillers.....	2.7	6.4	15.6	17.3
Average dry weight (gm.).....	2.37	1.37	0.60	0.31
Leaf area (sq. in.).....	92.6	35.8	14.5	6.9
Average No. roots.....	37.5	24.5	13.2	9.4

The crop headed and ripened earliest in the densest plot. At maturity (July 18), the working level of the roots was 35 inches for the 4 N field and 39 inches for the normal planting. In the latter, roots were more numerous per plant and had a wider spread. The development and yield of the mature individuals was regularly higher in the 0.5 N plot, but the group response was usually greater in the higher densities (table 2).

TABLE 2.

Measurements.	0.5N	N	2N	4N
Average height (in.).....	31	30	29	24.5
Average dry weight tops per square meter (gm.).....	389	398	438	417
Average No. heads per square meter.....	178	216	293	534
Average length of heads (cm.).....	8.8	7.9	6.8	5.5
Average width of spikelet (mm.).....	12.1	11.4	10.3	9.8
Average No. spikelets with grains.....	16.2	14.8	11.8	9.0
Grain from 1,000 heads (gm.).....	902	855	681	679
Yield of grain per acre (bu.).....	19.0	21.0	23.7	21.6

Sunflowers.—These were planted in large plots of cultivated soil in rows and spaced 2, 4, 8, 16, 32, and 64 inches apart, and the efficient factors determined. Measurements were made at several intervals on length and diameter of stem, size of leaves, length of petioles, number of branches, deterioration of leaves, photosynthetic area, dry weight, root extent, etc., and later of the size and weight of the flower heads, number and size of seeds, etc. Competition began almost immediately in the 2-inch plantings, which grew most rapidly at first, but they were soon outstripped by the 4-inch, and these in turn by the 8, 16, and 32 inch plantings. On August 5 the heights ranged from 40 to 93 inches through the several plots; in the 64-inch plot, where the competition for light was slight, the plants were 86 inches tall. The stem diameter at the base varied in the sequence of density from 5.7 to 45 mm., the average

number of green leaves from 4 to 28, the average leaf-area from 128 to 8,430 square inches, and the average dry weight from 2.1 to 491.4 gm. The working depth of the roots was 12 inches for the 2-inch plantings, 37 in the 8-inch and 46 in the 32-inch plot.

Control Cultures.—Sunflowers and wheat were grown in galvanized-iron containers 12 by 12 inches square and 24 inches deep. These held about 170 lbs. of moist fertile soil and were arranged in series of fives. Sunflowers were planted at the rate of 2, 4, 8, 16, and 32 plants in each series and wheat at the rate of 2, 8, 16, 32, and 64, a gravel mulch being used to cut down evaporation. In the first series the plants competed for nutrients, water, and light, each container receiving from time to time the weighed amount of water transpired by the culture of two. In the second series an equal optimum holard was maintained in each container, but in spite of this competition existed for nutrients and light. In a third series both water and nutrients were kept up, and in this the competition was for light alone. In still another, the shade was equalized by artificial means in the several containers so that competition for light was approximately the same. As a result it was possible to evaluate the effects of the several factors in competition. Duplicate and sometimes triplicate series were run so that the various measurements, as well as dry weight and root extent, could be determined at different periods. Marked differences in development had occurred under the different conditions by July 1 (table 3). In other experiments, 8 sunflowers were grown in containers in soil with deficient, optimum, and excessive holard or nutrients and in varying intensities of light.

TABLE 3.

Measurement.	Competition for water at densities of—					Optimum holard.				
	2	4	8	16	32	2	4	8	16	32
Average height (cm.).....	76.5	77.7	69.8	66.2	46.6	77	87.5	75.4	80.2	71.4
Diameter of stem (mm.)...	9.8	8.6	6.8	5.6	4.0	10	9.9	8.1	7.2	6.2
Length of largest leaf (cm.)..	15.3	15.4	11.2	9.8	7.8	16.0	17.5	13.6	10.6	10.3
Width of largest leaf (cm.)..	11.7	11.7	8.2	6.4	4.8	13.0	12.9	9.6	7.5	6.3
Average No. fully grown leaves.....	11	10.2	7.6	6.6	4.0	12.0	11.4	8.2	7.8	6.6
Average leaf area per plant (sq. in.).....	288.0	266.5	129.5	73.3	39.0	361.6	339.6	176.0	116.2	90.2
Average dry weight per plant (gm.).....	5.4	5.3	2.8	1.9	1.0	7.0	7.4	3.6	2.4	2.1

The Natural System of Angiosperms, by F. E. Clements and E. S. Clements.

The Besseyan system, which was undoubtedly the most consistent of the many endeavors to arrange flowering plants in a natural system, has been subjected to various ecological and statistical tests for nearly two decades. These have led to its modification from time to time, the most significant change being the application of the basic principles of phylogeny to the wind-pollinated plants. The artificial group of "Apetalæ" has remained the stumbling block of systematists since the time of Jussieu and, while Bessey distributed them all in accordance with their general relationships, the stigma of "degeneration" has steadily clung to them. From the viewpoint of pol-

lination ecology and consequent evolution, such flowers have been as highly specialized as the insect-pollinated ones. Indeed, the grasses, ragweeds, walnuts, and chenopods represent the highest degrees of advance attained by flowering plants. With experimental pollination as the basis, the thorough application of evolutionary principles has effected only minor changes in the phyla of insect flowers, but has wrought a revolution in the treatment of wind flowers. The outcome has been to throw the several phyla into essential harmony with each other and to produce a system at once deeply rooted in the past and capable of greater refinement in the future.

Leaving the question of their origin aside at present, all Angiosperms are regarded as having developed from Ranales, from which have sprung three great coordinate centers, Liliales, Rosales, and Geraniales, all under the controlling influence of insect pollination. Each of these centers has then been subjected to the effect of wind pollination also, with the consequence that it has given rise to two divergent phyla, each terminating in the highest expression of its type. Thus, from Liliales have come the insect-pollinated Orchidales and wind-pollinated Poales; from Rosales have arisen Asterales with the terminal Ambrosiæ, and Fagales; and from Geraniales have sprung Lamiales and Chenopodiales. In addition, the roses have produced the short phylum of Myrtales and Cactales. A full but condensed account of this system is ready for publication.

With the natural system as outlined for a basis, an endeavor is being made to gradually transform phylogeny from a comparative into an experimental subject. While the view that phylogeny is necessarily a mirage of opinion is incorrect, it can not be denied that most systems have contributed some support to it. This is partly because few attempts have been made to apply accepted principles consistently and rigorously, and partly because of the fetich of "degeneration." It is possible to eliminate these faults by the comparative method, but even then the methods of experimental evolution are indispensable to final objective judgments, particularly where the morphological evidence is conflicting.

The experimental attack is threefold, resting primarily upon the methods of experimental evolution but supported by basic studies in experimental pollination and correlation. This is directed in the first place at the genera that afford the best connections between orders and between families, but comprises also the typical and aberrant members of the chief strategic groups. The short lines of descent within families and orders, which are younger than the main phyla, are especially favorable subjects for analysis, as in ranals, rosals, composites, etc. The results already obtained make it clear that certain traditional canons of evolution are unsound, notably the one to the effect that characters once lost can not be again developed, and this conclusion is reinforced by comparative statistics derived from the large families. It is a demonstrable fact that staminoids and pistilloids can be again changed into stamens and pistils, and the ease with which the corolla can be manipulated suggests that this can be restored in apetalous forms of relatively recent origin, a conclusion equally valid for ray-flowers.

Experimental Evolution and Taxonomy.

PETRAN TRANSECT AND GARDENS, BY F. E. CLEMENTS AND W. T. PENFOUND.

The major emphasis for the season has been placed upon adaptation to light and to water by means of sequences and gardens. The latter have

proved more practicable, owing to the control afforded by fencing, but the sequences have the unique value of reproducing in the same transect the natural experiments by which new forms have already been found to originate. Two new gardens have been added to the three established last year, thus furnishing a series of five from sun to full-shade at a value of 0.04. The majority of the subdominants of the montane climax have been transplanted into each of the five gardens and the more plastic have begun to show striking changes. These are especially noticeable in the case of *Smilacina*, *Achillea*, *Geranium*, and *Erigeron*, practically all the vegetative characters exhibiting distinct modification. The inflorescence has changed less as a rule and the structure of the flower least of all, as was to be expected. With rare exceptions, shade-forms that were moved into less dense shade or into sun blossomed more abundantly, while sun-forms transferred to the successive shade gardens flowered much less or not at all.

The effect of habitat inversion is being followed by means of shade-tents placed over natural groups in position and by the removal of shrubs or trees to subject shade plants to sunlight. The shade-tents are constructed to fit the community concerned and consist of lath or of cloth of varying thickness needed to secure the intensities desired. In many cases, an awning is preferable to a tent, owing to the better circulation permitted, but it must be larger in order to keep the plants constantly shaded. The light values sought for the series are 0.5, 0.1, and 0.01, but these will doubtless be modified for other species. The cleared areas are a meter square and are located in *Quercus*, *Prunus*, or *Salix* scrub, in which the average change effected has been from a light value of 0.01 to full sunlight.

A pool, for effecting the widest range of adaptation to water, has been constructed in the montane zone at the Alpine Laboratory. This permits a series of decreasing holard from submerged and floating through amphibious and saturated to xerophytic, the land values being approximately 30, 15, 7, and 3 per cent. The soil is the same throughout. The water is led from a mountain brook and is much colder than in the ponds and lakes of the plains, thus also permitting transplants between the two, with the temperature difference controlling. The most important forbs, grasses, and sedges of the montane zone, especially those with a hydrophytic tendency, have been planted in 5-stage transects from the amphibious zone to dry land, in order to determine the limits of ecesis as well as the adaptation to the water and air contents.

On the intake side, the entering brooklet has been spread over the coarse gravel soil to form a swamp, almost glacial in temperature, in which hydroid mesophytes in particular have been planted. *Epilobium angustifolium* during the first summer has made an astounding response to the cold saturated soil. The stature has decreased from 4-6 feet to 8 inches, the leaves from 6-9 by 0.5-1 inch to 2-3 by 1-1.3 inches, and the raceme from 1-2 feet with 25-75 flowers to 2-3 inches with 5-6 flowers, while the petals are distinctly larger and the bracts leaf-like. The technical characters of the style alone separate the new form from *E. latifolium*. Even these had disappeared in a neighboring xeroid dwarf of *angustifolium*, in which the base of the style was nearly or quite glabrous and the stamens as long as or longer than the style.

The natural experiments in adaptation were more numerous and striking than for many years. This was evidently due to the fact that the winter and

spring were wet, and the summer almost wholly without efficient rains. As a consequence, the plant-body made nearly normal growth at the expense of stored holard, but this was inadequate for normal floral development, and the flowers of many species were greatly reduced in number and size, and often modified in form. The most remarkable example of this was furnished by *Campanula rotundifolia*, in which the flowers in moister situations were considerably smaller than usual, viz, 15 to 20 mm. deep and wide, the lobes being one-third as long as the tube. The commoner form in dry places strongly suggested *C. uniflora*, the flower being more or less horizontal and narrow, 8 mm. deep and 5 mm. wide, with lobes cut to the middle. A similarly deeply lobed form possessed a corolla 10 mm. deep and 12 mm. wide, while a third had a corolla 12 mm. deep and 20 mm. wide, with narrower reflexed lobes. This closely resembled *C. parryi*, which, like *uniflora*, is a species of xerophytic habitats. On exposed slopes the flowers of *Castilleja miniata* were reduced to a length of 2 to 2.5 cm. and had become essentially those of *C. parviflora*. In general, there was a close correspondence between the adaptations in natural and control cultures, indicating that the latter accurately reflect the origin of new forms in nature.

Sierran Transect and Gardens, by H. M. Hall and H. L. Mason.

Transplants along the Sierran Transect were subjected to exceedingly unfavorable conditions because of the unprecedented drought and the proximity of forest fires. At Mather, the 4,500-foot station, the plants set in 1922 were so well established that almost no loss was suffered, but among the 500 plants moved into the adaptation gardens last year there was a mortality of about 30 per cent, in spite of frequent watering and heavy mulching to check evaporation. Much better results were obtained at the higher altitudes because of the more favorable climatic conditions. Although no new transplants were made on this transect, about 100 plants were assembled from various parts of the West and held in the nursery for planting when conditions become more promising.

At the coastal stations the plants have received constant attention and consequently have made a much better growth. Especially noticeable is the increased vigor of those brought from arid, semi-arid, and alkaline districts. This demonstrates that many species inhabit such areas, not from choice but because of the strong competition in otherwise more favorable places or perhaps because of lack of natural introduction. It also suggests that desert and alkaline districts should be given special attention in selecting economic plants for introduction. Transplants of *Chrysothamnus*, *Parthenium*, and the shrubby *Atriplex*es make better growth here than in the Great Basin and in Mexico. A form of *Atriplex argentea*, which in Nevada becomes only 8 inches high and is sometimes taken to be a distinct species (*A. hillmani*), attains a height of 5 feet in Berkeley and assumes exactly the habit of typical *argentea* grown in the same garden. This result and recent observations on variation in Nevada prove that *A. hillmani* is only an ecologic form. On the other hand many apparently trivial forms exhibit great constancy in their characters. Thus, minor variations of *Artemisia vulgaris* assembled from widely separated stations show no modification in such features as cut of leaf and nature of pubescence. These are believed to represent genetic strains, or phenotypes, too numerous and too closely similar to receive taxonomic recognition but too constant to be entirely ignored. Similar results obtained with *Achillaea*,

Sisyrinchium, *Eriogonum*, and other genera demonstrate the futility of the multiplication of small species in these genera.

Taxonomy of Haplopappus, by H. M. Hall.

The preparation of a monograph of this complex group of the Compositæ is in progress. Field studies have been made in California, Oregon, and Washington, especially at type localities, and material assembled for statistical and experimental purposes. Transplants in the subgenus *Pyrrocoma* have been especially successful. Roots of the various species and forms are planted under uniform conditions in order to test the dependence of certain characters upon the environment. A reverse of this experiment consists in growing roots of apparently identical plants under different conditions of light, soil, and moisture. The results indicate that such features as dentation of leaf, type of inflorescence, and size of head are modified with difficulty, while size and shape of leaf and stature are readily influenced by the environment. However, the racemose type of inflorescence shows a tendency to become paniculate under the influence of cultural conditions, and this change can be induced also by mutilations. Although the type of inflorescence still remains as an important feature for the recognition of species, these changes suggest that forms with quite different methods of branching may nevertheless be of close genetic relationship.

Taxonomy of the Madinæ, by H. M. Hall.

Experimental studies on this subtribe of the Compositæ were considerably extended during the year. Sixteen species and subspecies were brought under control in greenhouse and field and subjected to various treatments in order to test the nature of the characters represented. These treatments consisted in changes in the amount of moisture, light and heat, and in soil modification through the action of various chemicals. Pruning and other mutilations designed to modify the food-supply were also practiced. The results will be utilized in determining the degree of relationship of the various forms and will also serve as a guide in the evaluation of characters to be used in a taxonomic monograph of the group now in preparation.

Detailed studies of one collective species of *Madinæ* are reported upon below.

The Hay-field Tarweeds, by E. B. Babcock and H. M. Hall.

This study was an outgrowth of the larger one concerned with the taxonomy of the *Madinæ*, the subtribe to which the hay-field tarweeds (forms of *Hemizonia congesta*) belong. It is the culmination of garden and greenhouse experiments and of field and herbarium studies begun as far back as 1912. The chief interest at this time is to determine whether or not it is possible to combine the genetic, ecologic, and taxonomic viewpoints in the solution of a problem in phylogeny. The results show not only that such a combination can be effected, but also that this is absolutely essential to the final solution of the broader problem of the origin of species.

On applying this combination of methods to the hay-field tarweeds, it is found that all belong to one stock and are best taken as one collective species. The principal forms involved are *Hemizonia congesta*, *H. luzulæfolia*, *H. l. lutescens*, *H. citrina*, *H. rudis*, *H. clevelandi*, and 2 subspecies to be described

as new. These and numerous minor variations are so closely united by intergradations and by demonstrated hybrids, and the genetic behavior of all is so similar that the whole assemblage is viewed as constituting one interlocking group. The evolutionary tendencies within the group have resulted in the production of 6 subspecies and numerous minor variations. The phylogeny of these has been studied and a chart prepared to illustrate the supposed relationships. Results of inbreeding and crossing have been studied in detail and the general conclusion is that numerous hereditary variations appear to have originated through mutation and that some of the characters are inherited according to Mendelian principles.

A paper dealing with this investigation is now in press (Univ. Calif. Pub., Botany).

Rubber Plants, by H. M. Hall and Frances Long.

Studies of native American rubber plants have been continued in collaboration with the office of Crop Acclimatization, United States Department of Agriculture. The desert milkweed (*Asclepias subulata*), the most promising species, is being grown under various types of agricultural conditions on the Colorado Desert. Seedling plants make a growth of 3 feet in height the first season, when given moderate irrigation, and yield 3 to 9 pounds of tops when cut. They readily reproduce from the cut stumps and make a much more rapid and dense growth the second year. Even under a rainfall of 3 to 6 inches and without irrigation, this species grows rapidly from seeds and roots in the Gila, Colorado, and Mohave Deserts. The results of growth under a wide range of ecologic conditions will be reported upon later through government publications.

In testing *Chrysothamnus* as an agricultural plant in Nevada, no difficulty is encountered in obtaining a good stand of seedlings in boxes or in transplanting these to the field under favorable conditions. However, the present season has been exceptionally unsuitable to the young plants and many of these, set in heavy alkaline soil, have been killed. Successful field plantings were made at Shafter and at Berkeley, California. Plantings made at Fresno and at Davis were less successful because of very unfavorable climatic conditions and pests that killed the young seedlings. Because of reductions in government appropriations, it seems unlikely that the experiments with *Chrysothamnus* will be continued.

Latex and Laticiferous Tissue, by Frances Long.

Latex plants have been grown in both greenhouse and garden under various conditions of water-content and light intensity, with respect to the modification of latex-bearing tissues and the content of latex and rubber. Shade-tents consisting of cheese-cloth, muslin, and black calico were placed over a number of species in the greenhouse and also in the field, and striking adaptations were obtained. Histological material was collected from all of these at various stages of development, and a large number of slides prepared for the study of the origin of milk-tubes and their changes under the influence of efficient factors. The unusually dry season in Colorado made it possible to secure a large amount of material in nature for comparison with that collected the preceding year, which was exceptionally wet. It is hoped that this will throw some light upon the relation between latex and resins.

As the most important and interesting of our native rubber-plants, an especial endeavor has been made to trace the life-history of *Asclepias subulata* in detail and to determine its range of adaptation to the various factors, as well as the effects upon the amount and composition of the latex.

Distribution and Behavior of Soil Algæ, by G. W. Goldsmith and Lee Bonar.

In connection with the project in soil aeration, a comprehensive study of the distribution, behavior, and effect of the algæ found in the soils has been initiated. The major objective is the relation between algal activity and the air-content of the soil, but this is best approached through a knowledge of the species, their occurrence and life-history. The culture method in general was that of Bristol (Ann. Bot. 1920), all cultures being made in duplicate with numerous blank checks. The first ones were made early in March and others were taken in late spring and summer, about 80 per cent developing a growth of algæ. After June first the cultures were kept in the greenhouse and this had a favorable effect upon their growth. Each sample consisted of 5 gm. of soil taken at the level desired and was accompanied by a full record of time, place, soil, depth, vegetation, altitude, etc. A special endeavor was made to secure cultures from all the available types of soil, loam, clay, sand, gravel, leaf-mold, etc., and to take into account the important variations in each habitat, such as holard, light intensity, cover, cultivation, time, place, etc. Samples were also taken at different soil levels, at various altitudes, and in transect series leading back from the edge of pond and swamp. Ultimately, it is hoped to make transplants from one soil, habitat, or altitude to another.

The algæ of the cultures have been chiefly blue-greens and 1-celled Chlorophyceæ. The one common filamentous member of the latter was *Ulothrix variabilis*. As a rule, the species of the higher altitudes tend to have thick gelatinous sheaths, but these are less common at lower elevations. Some of the species are generally distributed in the region studied, while others are restricted to special habitats. The algæ of limited range are such as *Nostoc minutum* and *N. aureum*, which are found only in the alpine climax, a fact in accord with their reported occurrence only in Alaska and the Arctic regions. In general, samples from the alpine zone have shown growth from the surface level alone, while those from the lower zones and the plains have yielded algæ at depths of 4 and even 8 or 12 inches.

Climatic Cycles and Tree Growth, by A. E. Douglass.

The study of climatic variations shown in the growth-rings of trees has been extended to cover the entire southwestern region by means of a large number of groups of trees, mostly yellow pines 300 to 600 years in age. Five of these groups are from California, 8 or more from Arizona, 5 from New Mexico, 3 from Colorado, 1 from Utah, 1 from Idaho, and 1 from Nevada. This last from the Charleston Mountains shows intermediate characteristics in growth between northern Arizona and California. Several special groups have been obtained from Flagstaff, Arizona, to carry out studies of the effects of altitude and of "mountain shadow," or the protection of the east slopes of mountain ranges from prevailing westerly winds. The oldest yellow pine has recently come from near Flagstaff, a tree 640 years old that gives a very valuable record. A new group from near Prescott, Arizona, brings the

Prescott record of tree-growth up to date for comparison with the rainfall record which has been kept there since 1867. It also supplies material for studying more fully the climatic significance of false or additional rings in these mountain pines at relatively low elevations.

A trip was made in July 1924, to the Calaveras Grove of Big Trees, where only 5 specimens were obtained, owing to the absence of logging. Two of these were increment cores showing about 300 rings each from recently fallen trees, and were for the purpose of accurate dating. This precaution proved less essential, as the Calaveras trees cross-identify with the other groups of *Sequoia* farther south. As a result, cross-identification has been carried through the Calaveras, King's River, and Springville regions and without doubt applies throughout all the *Sequoia* groves in the Sierra Nevadas, though not to coast redwoods from Santa Cruz. A group of yellow pines was also collected from the vicinity of the Calaveras Grove to assist in cross-identifying between pines of Arizona and the sequoias of the Sierra Nevadas. It was collected at two levels, several thousand feet apart, and shows the effect of altitude.

All these groups will be studied in detail for climatic variations, but they confirm at once the dates of many of the droughts that show in the Arizona trees. Three major droughts were from 1573 to 1587, 1729 to 1741 and 1812 to 1823, of which the first mentioned was the most severe. These groups therefore furnish material for the study of droughts in the Southwest for the last 500 years.

Collections of fossil and buried trees have been obtained at Flagstaff (Arizona), Colma (California), Washington, D. C., East Wareham (Massachusetts), La Brea (California), and a piece or two from the Swiss Lake Dwellings. Nine new specimens from the Aztec Ruins in New Mexico have received "relative" dating with respect to others from Aztec and Pueblo Bonito, and a large number of sections or fragments of beams have been secured from Chaco Canyon. Pieces of burnt beams have proved almost as valuable as those from well-preserved beams after they were treated with paraffin.

Finally, a new longitudinal plotting instrument has been constructed, which rapidly reproduces the ring spacing on a scale from 8 to 35 times the original. It permits bringing each tree record to a standard scale before using it in the averages. In this process are used approximately the percentage departures from means instead of actual values, as in direct measurements formerly used. The results of the past six years are now in preparation for publication.

Changes of Climate and Vegetation, by F. E. Clements and E. S. Clements.

The extensive field work upon this problem has been completed and the comparative and statistical studies are under way in anticipation of publication during the coming year. This is an investigation of the physical, biotic, and secular causes underlying the present structure and extent of the five grassland associations and their ecotones with contiguous formations. It is based upon the principle of the climatic cycle and the consequent cycles in vegetation, and furnishes a dynamic approach to the character and events of the Recent period. The latter constitutes the mid-ground between ecology and paleo-ecology, since many of its effects are still plainly discernible in the structure and distribution of existing communities. Consequently, its study

affords by far the best test of the application of ecological principles to the past and of the validity of paleo-ecological conclusions as explanations of the present. The interdependence of climate and vegetation is the dominant theme in this complex of relations, in which a new note is supplied by the apparently reciprocal relation of the two.

The methods employed are essentially new, but they have been so thoroughly tested during the past six years as to leave no doubt of their merit. They are the method of (1) cycles, (2) indicators, (3) mass migration and evolution, (4) relicts, and (5) experimental vegetation. The first is basic and is accurately reflected in the next three, which are corollaries of it. The method of experimental vegetation permits the almost unlimited refinement of the evidence supplied by the others, and provides an objective standard of the utmost value for past processes. Thus, the interplay of the five methods assures a comprehensive, many-sided and fundamental analysis of the most fascinating and perhaps the most difficult of all problem complexes, the reciprocal relation of present and past.

The profound changes in grassland during the past 200 years have been caused by grazing and cultivation, but these have been periodically reinforced by drought. They have been progressive in nature, often resulting in permanent communities of a totally different character, while the action of drought is periodic and is frequently obliterated by the succeeding wet phase of the cycle. During the feral period, grazing must have had a cyclic effect in some degree, especially when it was a question of the enormous bands of buffalo. The effect of fire on grassland was less marked, owing to the perennial habit of the dominants, but it frequently played a decisive rôle in the competition between it and scrub or forest. All the modifications due to grazing and fire can be projected into the Recent period at their full value, but the responses due to climatic cycles have a much greater significance for reconstruction. The differences between the dry and wet phases of a sunspot cycle are often greater than an entire climate and the effect upon vegetation may simulate the shifting of a climax. As a consequence, such changes constitute a graphic indication of what took place in cycles of greater amplitude and during phases of much longer duration. In short, they are the best evidence available, and probably the best that will ever be available, of life movements on the vast grassy uplands, the fossil-plant record of which can never consist of more than the merest fragments.

Principles and Methods in Paleo-ecology, by F. E. Clements and R. W. Chaney.

The further application of ecological principles to fossil floras has practically demonstrated that the Mascall flora bears a precliseral relationship to the Bridge Creek, which is the next older flora in the Tertiary section of the John Day Basin. The Mascall flora includes a number of the forms typical of the redwood forest that characterize the Bridge Creek, but the presence of such species as *Quercus pseudolyrata*, *Aesculus simulata*, *Cercocarpus antiquus*, *Arbutus* sp., and *Quercus convexa*, indicates its close similarity to the plant community now living in the open borders of the redwood forest. Probably as a result of increasing aridity during the dry phase of a climatic cycle, these border species came to occupy the edges of streams and lakes, where their leaves and fruits were more readily fossilized.

A recent comparison of the leaves and seeds of modern *Thuja* and *Libocedrus* has shown that fossils doubtfully referred to the former are properly referable to *Libocedrus*. Through a further study of the species now associated with the redwood, it has been demonstrated that the leaves formerly referred to *Cinnamomum* in the Bridge Creek flora are actually those of *Philadelphus*, and that the leaves doubtfully considered as *Fraxinus* really belong to *Umbellularia*.

The driest season of record in the Pike's Peak region has led to a phenomenal variation in the leaves of the deciduous trees and shrubs, and has afforded an exceptional opportunity to determine their ecological significance. *Populus tremuloides* has exhibited the greatest differences, ranging from leaves fairly typical of *P. tremula* and of several species of cottonwoods to leaf-forms that strongly suggest wholly unrelated genera. All of these were found within a few hundred yards of each other on the same slope above the brook in which the leaves collect. Similar though somewhat less striking differences were found in the leaves of *Betula*, *Prunus*, *Quercus*, and *Symphoricarpus*. These are not only eloquent as to the value of the specific criteria in many fossil horizons, but also lend support to the view that plant species are much older than ordinarily assumed, as well as fewer in number. They have moved back and forth with changing cycles of climate and adapted themselves to new edaphic habitats, but usually without over-stepping the limits of the species.

A critical re-examination of phyletic lines in Angiosperms is being made in the endeavor to place phylogeny on an experimental and objective basis. One of the primary objects sought is to give phylogeny definite value among paleo-ecological methods with respect to the relative dating of evolution and migration maxima.

Grazing Ranges of Northern Arizona, by J. V. G. Loftfield.

The results of an extensive investigation of the ranges of northern Arizona have been summarized this year, and will soon be published. The important formations have been mapped, their structure determined and their value as range estimated quantitatively. The life-histories of the most important grasses have been studied and the successions initiated by prairie-dog and grazing disturbances have been traced in considerable detail.

The grazing types of the yellow-pine forest are three in number. The ground cover of the savannah, as well as the burn parks, consists chiefly of *Muhlenbergia gracilis* and *Festuca ovina arizonica*, with smaller quantities of *Elymus sitanion brevifolius* and *Stipa viridula vaseyi*. *Stipa comata* was formerly present, but has disappeared under overgrazing. This forage type yields a maximum of 1,400 lbs. of hay to the acre in the open. The rocky hills and slopes contain *Lycurus phleoides*, *Andropogon scoparius hirtiflorus*, *Muhlenbergia emersleyi*, and several species of *Aristida*. The hydrosere parks comprise *Agropyrum smithi*, *Sporobolus cryptandrus*, and *Stipa v. vaseyi*. This latter type produces a maximum of 1,800 lbs. of dry forage to the acre. The average for all the grazing types in the yellow-pine forest is naturally much less.

The original forage-type found in the juniper-pinyon woodland and the savannah below it consisted of true mixed prairie, the tall-grasses being *Stipa comata*, *Sporobolus cryptandrus*, *Koeleria cristata*, and others of less importance. The short-grass layer is practically pure blue grama (*Bouteloua*

gracilis). Originally this forage-type produced a maximum of 950 lbs. of dry forage to the acre, but in consequence of the total extinction of the tall components over almost the whole area and their replacement by worthless shrubs and weeds, the maximum has fallen to 390 lbs. per acre.

The two types of grassland below the juniper-pinyon savannah are mixed prairie and desert plains; but through overgrazing the former has been reduced largely to *B. gracilis* and *Muhlenbergia gracillima*. With these are associated *B. eriopoda*, which marks the transition to the desert plains. In this region these are often dotted with *Yucca*, *Prosopis*, and other shrubs to form savannah. This type of grassland is composed chiefly of *B. eriopoda* associated with *Sporobolus cryptandrus* and several species of *Aristida*. Towards the desert edge, *Hilaria mutica*, *H. rigida*, *Muhlenbergia porteri*, and several other grasses, chiefly annuals, become much more common. The maximum yield of the short-grass type is 895 lbs., although an unfavorable season will cause it to drop at times as low as 85 lbs. per acre. The maximum yield of the desert-plains association has not been determined, since overgrazing has practically destroyed all but the least useful grasses over the greater part of the area.

The life-histories of *Stipa comata*, *Agropyrum smithi*, *Sporobolus cryptandrus*, *Bouteloua gracilis*, *B. eriopoda*, and others have been worked out in considerable detail. The results indicate that under range conditions the ecesis of the grasses is less than one per cent of the seed production, even under the most favorable conditions. *Stipa comata* is probably doomed to extinction, although its maintenance in the juniper-pinyon savannah would more than double the forage value of this type. While there is no question that it can be successfully regenerated and even introduced, this is impossible without adequate control of the range.

Researches in Bio-ecology.

RODENT DAMAGE ON ARIZONA RANGES, BY W. P. TAYLOR AND J. V. G. LOFTFIELD.

The studies on the experimental plots in northern Arizona and on the Santa Rita Range Reserve have been carried forward actively during the year.

TABLE 4.—Blue-grama forage-type in juniper-pinyon savannah, Williams, Arizona.

Plot.	Total protection.		Rodent-grazed.		Cattle and rodent grazed.	
	1922	1923	1922	1923	1922 (Ac 6)	1923 (Ac 7)
Yield of forage (grams)...	43.7	15.6	7.3	6.5	2.6	2.4
Yield of weeds (grams)...	51.1	18.8	22.0	20.4	60.4	62.5
Yield of all plants (grams)...	94.8	34.4	29.3	26.9	63.0	64.9
Yield per unit area (grams).....	1.0	0.4	0.2	0.2	0.2	0.09
Area occupied by grass (sq. dm.).....	43.86	36.90	32.50	28.62	31.20	27.10

The results from these plots grow more significant with each additional season and will soon demand even more intensive consideration. It has been found impossible to maintain prairie-dogs within the inclosure at Coconino Wash and this has been changed to a cattle exclosure, through which the rodents may range freely. The most successful area for the past two years has been the one at Williams. The fences are in good condition, and a representative

colony of prairie-dogs has been maintained in the grassland surrounding the plots, as well as in the rodent-grazed one. The summary for the two years is presented in table 4, which shows the weight of forage and weeds produced per square meter in the three plots, the area actually occupied by the grass (blue grama, *Bouteloua gracilis*) and the weight of grass per square decimeter of mat (yield per unit area).

The results are for one quadrat in each plot, except the cattle-grazed plot. The first clip quadrat (Ac 6) was destroyed during 1923 and was replaced in October by another (Ac 7), from which the data for the season were taken.

CLASSIFICATION OF THE MAMMAL COMMUNITIES OF THE WESTERN UNITED STATES,
BY L. R. DICE AND R. T. HATT.

A classification of animal communities is essential to the critical study of the factors that control the distribution of species and determine animal evolution. Such a classification will also be useful in life-history studies and in other investigations. Up to the present time no system for the classification of animal communities has come into general use, nor have the animal communities of more than a few small areas in the United States been described. The present investigation has been begun in the hope of demonstrating a satisfactory method of classifying animal communities and at the same time describing the mammal communities of parts of the western United States.

During June and July, seven weeks were spent in a reconnoissance from southern California through northern Arizona and northern New Mexico to Colorado. By trapping and by field observations an attempt was made to determine the dominant mammals in the most important habitats of the region traversed, special attention being given to the rabbits and pikas (*Lagomorpha*). Although the data secured on mammal communities are very incomplete, they are of value in showing the differences in the several ecologic formations and in the more widespread associations.

In the later part of the summer, six weeks were spent in an intensive study of the mammal communities of eastern Colorado. The method employed was to study carefully the mammals of each area that by virtue of its vegetation, soil, or other features appeared to offer different living conditions for mammals. In such areas 50 to 200 mammal traps of various sizes were set and left for from one day to a week, the mammals being removed once or twice per day. In addition, all possible sight records of mammal species were secured. Specimens of each species from each locality were preserved where needed to make the specific identification certain. For the larger species it is impossible to secure many records or specimens, and for these species one must depend largely on information secured from trappers and ranchers.

Most attention was given this season to the Pike's Peak district, but camps were also made near Devil's Head Peak, Nederland, Fort Morgan, Limon, and in the Black Forest near Colorado Springs. The observations for most of these regions were preliminary in character. This is especially true of the grassland, where the very dry season made study unsatisfactory. However, it is evident that many species of mammals in the regions studied show a close correlation with certain types of habitats and that the mammal communities correspond closely in distribution with the plant communities.

CORRELATIONS BETWEEN PLANT COMMUNITIES AND GRASSHOPPER ASSEMBLAGES,
BY A. G. VESTAL.

A study of the grasshoppers of the plains and eastern slope of the southern Rocky Mountains was begun about twelve years ago and continued at intervals since. This summer's work is an effort to bring the extensive phase to a close, in preparation for intensive work on life-histories and food relations. The method consists in making a census of the grasshopper population of each of many areas representing various plant communities. The relative abundance of the different species is estimated and used in evaluating differences in the grasshopper population in various habitats. The problem is complicated by the fact that many plant communities extend through various soil types, and even more so by the extreme mixtures of grassland and other associations in the mountain-border zone. In general, it is found that the grasshopper population of a habitat with mixed vegetation is itself a mixture, and that the mixtures of mesa grasslands, of closed bunch-grass, of open pastured bunch-grass, and of short-grass show certain differences, though more in relative abundance than in the species.

The family Acridiidae has been found to show interesting correspondences in distribution with vegetation and with soil types. Some few species are associated with one or more host plants, as *Æoloplus* on chenopods, and *Campylacantha* on *Artemisia*, etc., but most of them are general feeders. Of these, a number are associated with a particular soil, such as *Achurum* and *Melanoplus angustipennis* in sand, others in loam, and still others in gravel. This is largely because the female selects a more or less definite type of soil in which to lay eggs. Some are found usually upon plants of a certain growth-form, as *Achurum* upon the stems of bunch-grasses, and *Melanoplus bivittatus* upon tall herbs, while others (especially the long-winged *Cedipodinae*) are most frequently seen resting or walking upon bare ground.

The faunistic variations with altitude and latitude are marked. The high-mountain fauna, with only a few species, and the assemblage of the lower mountains are made up very largely of boreal species ranging over most of the northern states and Canada. The mountain-border, plains, and southern plains species are those of western and southwestern North America. The low-mountain assemblage includes meadow forms (*Chlœaltis*, *Stenobothrus*), dry grassland forms (*Camnula*, *Melanoplus atlantis*, *M. infantilis*, and others), a group characteristic of mountain bunch-grass and open pine-forest undergrowth (*Melanoplus fasciatus* and *Trimerotropis cincta*), as well as the bare-gravel group (*Trimerotropis* spp., *Circotettix*, *Spharagemon*). The mountain-border assemblage exhibits the greatest mixture and the largest number of species.

Scrub and woodland are markedly deficient in grasshoppers, and thus far not a single individual has been found in closed forest, although forest species are known in other regions. Several species seem to be characteristic of scrub and of the bases of junipers, but these occur only locally and are poor in individuals. The lowest driest plains are those of the Arkansas valley and they contain grasshoppers not found elsewhere east of the mountains in Colorado. There are characteristic differences between the grasshopper assemblages of sandy-loam plains and of the clay plains of Pierre shale. The sand-hills areas especially are marked by species not found elsewhere. It is probable that these differences are largely successional in character, since there

seems to be a close general correspondence between the movement of plant populations and grasshopper assemblages in various types of succession.

HABITS AND REACTIONS OF *SCAPHIOPUS HAMMONDI*, BY G. W. GOLDSMITH.

Scaphiopus hammondi, the western spadefoot toad, which occurs on the dry plains in the vicinity of Pike's Peak, seeks water only during the breeding season when the early rains of spring fill the ponds. The period during which the ponds retain water in the early summer suffices for the development of the eggs. For the rest of the year, the adults are found in the soil or on the surface if the weather is rainy. In connection with a study of the habits and reactions of this xeroid amphibian, 100 individuals were collected at the breeding pond and placed in an enclosure 12 feet square, located in the mixed prairie. The plot was inclosed by wire screen set 18 inches below the surface of the soil and with the edge turned in both above and below the soil. Frequent observations were made of the number of individuals on the surface, their behavior, and the weather conditions. At intervals a number of individuals were removed from the soil, the number and depth of the burrows determined, and the contents of the alimentary tract identified and counted.

Scaphiopus hammondi is very sensitive to changes in atmospheric humidity. It remains under ground to a depth of 1 to 2 dm. during the day. During the night or at the approach of rain, it comes to the surface, often remaining with head protruding. During humid nights it frequently travels some distance, digging into a soft place in the soil at the approach of day. If protected from the wind and direct sunlight, individuals will often remain on the surface until the middle of the forenoon. The food consists chiefly of surface insects, comparatively few being taken during the breeding period.

Research in Hay-Fever.

PACIFIC COAST AND GREAT BASIN, BY H. M. HALL.

The work of the year has been essentially in continuation of that of the preceding, the chief attention being given to the fundamental principles of group reactions, in addition to regional and pollen surveys. Charts exhibiting the degree of relationship between the species of important genera and families have been employed to interpret the sensitivity obtained in various cases. While the results clearly indicate the significance of genetic relationship, it is equally clear that different individuals may react in very different manner to the pollens of related species and genera.

ROCKY MOUNTAIN AND MISSISSIPPI VALLEY REGIONS, BY F. E. CLEMENTS, W. V. MULLIN, E. S. CLEMENTS, AND EDITH WHITCOMB.

Apart from the clinical results, the major work of the season has been with the bacterial contamination of pollens and pollen-extracts. Cultures have been made of 155 collections, representing 64 kinds of pollen obtained during different years or at different parts of the same season. The apathogenic *Bacillus subtilis* was found in the collections of all species, with the exception of the cat-tail (*Typha latifolia*). One bottle of the pollen of cottonwood (*Populus deltoides*) yielded in addition an evident *Streptococcus*, but cultures on blood-agar demonstrated that this was not one of the common virulent types. A number of tests were made to determine whether the presence of the hay-bacillus in the extract modified the reaction in any way, but no difference could be observed in the action of extracts freed from the bacillus and

those containing it. The bacilli were readily removed by means of a Berkefeld filter.

The extreme dryness of the season intensified the response to hay-fever and rendered possible a more decisive test than usual of the value of pollen therapy. About twice as many patients received pre-seasonal as did seasonal treatment, and all those completing this treatment received benefit ranging from 90 to 100 per cent. Of those given seasonal treatment, one-half were benefited to the extent of 90 to 100 per cent, a fourth to the extent of 75 per cent, and one obtained no relief. Three of this group did not begin treatment until the last of August, but in spite of this fact, they received decided benefit, thus confirming the earlier conclusion that seasonal treatment is always indicated when pre-seasonal has been missed. The most significant result was the apparent immunity developed by a patient treated for two years, who exhibited no symptoms of hay-fever during the entire season. The possibility of acquiring a progressive immunity was also indicated by the response under different periods of treatment. Patients treated for the third year obtained complete relief in 44 per cent of the cases, those for the second year in 30 per cent, and those for the first year in 27 per cent.

Progress has been made on the hay-fever manual, especially in charts of relationship and the color plates of hay-fever species and pollens, and it is hoped this will permit its completion during the coming season.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology*. (For previous reports see Year Books Nos. 2-22.)

Several circumstances concur in making this a fitting time to summarize the progress of this inquiry so far as it relates to the genesis of the earth. At the same time it is proposed to designate the unworkable factors that are to be dropped out of the further inquiry. Thus far an endeavor has been made to restrain the natural tendency toward final conclusions and to keep all genetic postulates on the trial list in pursuance of the method of multiple working hypotheses. But in an inquiry in which absolute determination is unattainable, and whose working value lies largely in its bearings on the later stages of the earth's evolution, the time comes when formal trial should give place to conclusions, or at least a closing balance of evidence. It is an essential part of the method of multiple working hypotheses that, after due trial, dead and dying hypotheses should be cleared away, to disincumber the field in behalf of more promising studies. As two decades have now passed since the planetesimal hypothesis of the origin of the earth and its planetary kin was put into the competitive list, it seems time to close the trial so far as this inquiry is concerned, and clear the field for further work in the line of what seems to have survived the trial.

Perhaps it should be stated, at the outset, by way of explanation, that this inquiry began about a decade before the Carnegie Institution was established. The study at the first related chiefly to *the dynamic peculiarities of the planetary system*, stimulated by the disclosure of weaknesses in the genetic views then current. The work under this Institution began essentially with the construction of the new hypothesis offered to meet the disclosed defects, and the work has remained essentially constructive ever since. It is to be noted further that the objective in this study is *the genesis of the earth*, for in that lie the fundamentals of historical geology. The origin of the earth, however, involves that of the planetary family; but there has seemed to be no reason to include the genesis of stars, and so, though the study has been somewhat cosmological, of necessity, it has related only to *planetary* cosmology, not to *stellar* or *general* cosmology.

As a device to put as much as may be into the least space, a list of what seem to be requirements that must be met by any tenable theory of genesis will first be given, after which a classification of hypotheses according to their fundamental tenets will be offered as the clearest and briefest way of bringing the whole field into view. On the basis of this conspectus, brief notes will indicate the conclusions reached.

FEATURES OF THE PLANETARY SYSTEM THAT SERVE AS REQUIREMENTS FOR A TENABLE HYPOTHESIS OF PLANETARY GENESIS.

1. A true theory of planetary genesis will necessarily give precedence to the motions, energies, and related *dynamical* properties of the planets, and a secondary place to their statistical features.

2. A true hypothesis must distinguish definitely between the class of solar attendants that moves in concurrent, sensibly concentric courses, and the class that moves in heterogeneous discordant courses, because the results of their

aggregation, respectively, are diverse in trend. The former class includes planets, planetoids, planetesimals, satellites, and satellitesimals, all of which are actuated by *planetary* dynamics in the distinctive sense. The latter class includes meteors, meteorites, and comets, whose dynamics are more or less hostile to evolution of the strictly planetary type.

3. The concurrent class is assembled in a thin disk, and this thus becomes a decisive criterion. This disk occupies but a small portion of the sun's sphere of control, while the discordant class occupies almost all of it, in an attenuated way, and taken as a whole constitutes a great spheroid. To become a thin disk of the planetary order, this great spheroid would need enormous concentration as well as radical change in revolutionary habit.

4. A critical hint as to the nature of the genetic process lies in the fact that *neither* the concurrent nor the discordant class is yet fully concentrated. Each class shows some capabilities of aggregation, and some progress in it, but the degrees of progress are quite different and very suggestive. The aggregates of the concurrent class range from sizes too small for successful study up through a thousand or so bodies of the planetoid and satellite orders (which range from a few miles in diameter to a few hundred), and thence to planets which range from a few thousand to 88,000 miles (141,707 km.) in diameter. The discordant class ranges from particles too small to endure the atmospheric dissipation attendant on their plunge into it, up to materials that successfully endure this, ranging from ounces to pounds, tons, and a few tens of tons, but no body, not even a comet, is known to have mass enough to deflect sensibly even a satellite from its normal course (though the satellite sometimes changes the course of the comet). A logical search for a theory of genesis must take note of the great differences in capability of aggregation thus displayed in the same field and, so far as we know, under the same conditions of age and environment.

5. Mechanical theory confirms and adds to this naturalistic exhibit. Bodies in concurrent courses normally come together with relative gentleness and retain a relatively large part of their energy of motion. Bodies in discordant courses collide with greater violence, giving rise to greater heat which is dissipated; they also give rise to breakage and dispersion.

6. Nature's exhibit is further notable in that, so far as known, the discordant system of solar attendants, as the outcome of all the past, has not produced, captured, or otherwise come into possession of a single aggregate that approaches in size the smallest planet.

7. The limitations of aggregation of the concurrent class need also to be emphasized. Though four giant planets have been formed and four minor ones, yet the number of small aggregates vastly preponderates and the gathering of these into the larger aggregates, if it is to take place at all, is likely to occur only in the extremely distant future. The intimation is that even concurrency of motion and mutual attraction, acting at advantage, are insufficient for successful aggregation of the planetary order, and hence that not only were effective collecting nuclei provided in the actual case, but also orbital nodes by means of which conjunctions would arise.

8. The cause of the prevailing restraint of aggregation thus indicated is quite certainly found in *the dominance of translatory motions* and in the great energies such motions involve. These are greatly in excess of the effects of mutual attraction between small dispersed bodies. Unless small masses are

almost in contact with one another, the orbital movements prevail and the little bodies go on their individual courses regardless of the feeble solicitations of their fellows. Exaggeration of the power of direct attraction of small bodies in revolutionary motion is one of the most crowded pitfalls of cosmology.

9. A criterion of great service, in this respect, may be found in the dimensions of the spheres of control of the present planets. These spheres represent the maximum reach of collecting power thus far attained in the growth of the planets. At any earlier stage these spheres of control should have been smaller. As here used, they may be defined as that space about the planet within which it can control a satellite but outside of which it can not, permanently. From the tables of Laplace and Moulton (*Popular Astronomy*, 1899, 1-5), it appears that these areas of control are only a small fraction of that through which, under any of the leading hypotheses, the original planetary matter was scattered. For example, the diameter of the spheres of control of the Earth and Venus would both have to be increased more than 20 times to cover the space between them; those of the Earth and Mars, more than 40 times. It is to be noted, further, that even this control holds only for the favorable case of masses moving in courses *concurrent* with the controlling center. Even in this case, the mass controlled is not necessarily gathered into the controlling center, but may merely revolve about it as a satellite or satellitesimal. This criterion brings into vivid form the overwhelming dominance of revolutionary motion over bodies scattered through the planetary field. It emphasizes the necessity of effective collecting centers and nodal adjustments of orbits, if much growth is to be made from dispersed matter under planetary conditions.

10. In the light of the foregoing limitations, the concrete facts of the planetary system and of its relations to the sun become—even when stated merely as facts—scarcely less than specific mandates to framers of hypotheses. Their full meaning can not be set forth here. The masses of the planets are very small relative to that of the sun, ranging roundly from one-millionth to one-thousandth. The total mass of the planets is only about one-seventh of 1 per cent of that of the sun. Beside such limitations of solar partition as the smallness of these masses imply in themselves, their ratios raise questions respecting natural proportions in partition, which are too subtle for statement here but have bearings on the following decisive relations.

11. The distances to which these small separated parts are distributed, however they got there, range roundly from 30,000,000 to 3,000,000,000 miles (60,000,000 to 5,000,000,000 km.). The potential energy consumed in this distribution, however caused, is extremely great and peculiarly apportioned.

12. The question of room for such deployment is critical with some hypotheses.

13. It is peculiarly significant that the planets, notwithstanding their relatively small mass, carry 98 per cent of the value of revolutionary motion (moment of momentum) of the whole solar system; the sun, though it embraces 699/700 of the mass of the system, carries only 2 per cent. The proportions carried by the individual planets are equally singular and significant but can not be stated here. (Babinet, *Comptes Rendu*, vol. LII, 1861, 481; Moulton, *Astrophys. Jour.*, 1900, 103-130; Chamberlin, *Jour. Geol.*, 1900, 58-73.)

14. The orbital motions of the planets are such that the solar system quite surely has not been subjected to any appreciable disturbances from without

since it was formed, so that the constancy of moment of momentum, which is conditioned on the absence of effects from without, is assured. By the use of the present moment of momentum, the rate of rotation of the planets of the whole system may be computed by theoretically expanding it according to the laws of gases. The results of this form a decisive test for those theories that postulate gaseous or quasi-gaseous shrinkage resulting in centrifugal separation of planetary matter. Expanded thus to the sizes of the several planetary orbits, great discrepancies appear at all stages (Moulton, loc. cit.). At the orbit of Neptune, the rotation implied by the moment of momentum of the system was found less than a two-hundredth of that required to set off the matter of that planet by centrifugal action. The rate of rotation required to set off a ring or bunch of matter by centrifugal action would be reached only after the shrinkage had passed within the innermost planet's orbit. The requirements of the law of constancy of moment of momentum are among the most rigorous and trenchant of this long list, but they do not stand alone. The full strength of the requirements is only found in their combination.

15. The observed rate of rotation of the sun at its equator is about $1\frac{1}{2}$ miles (3 km.) per second. To set off matter for a planet at its present equator by centrifugal action would require a rotation about 200 times as fast as this. The motion of the equator of the sun is slower than the orbital motion of any of the planets. The innermost planet moves about 20 times as fast as the equator of the sun.

16. The plane of the sun's rotation is oblique to the plane of revolution of the planets severally, and to the invariable plane of the planets taken together. This obliquity is not large but as all interchanges of matter between the planetary system and the sun should tend to reduce this obliquity, it was presumably larger at the outset. This feature is a criterion bearing on the centrifugal separation of the planets, but, quite apart from that, the argument of heredity implies that obliquities should be derived from it by the planets. This is a matter of special interest to earth science because of the earth's strange obliquities.

17. The sun is highly eruptive, projecting small portions of itself to great heights. Taken in connection with radiation pressure, which quite certainly cooperates with eruptivity in the projection of solar matter, it is probable that some projected substances are occasionally shot even to the outer parts of the solar sphere of control, and perhaps even beyond. It is quite certain that this eruptive condition arises, in part at least, from the sun's prodigious radiation which inevitably induces violent convection, hence it has probably always been an outstanding feature of the sun since its radiation began. It is therefore a condition which calls for recognition in all theories that postulate the separation of planetary matter from the sun, as practically all planetary theories do. The eruptivity must probably either be an aid or a disturbing factor.

This list can not well be made to include all criteria that have actually been used, for some are too complicated to be briefly stated or too subtle to be set forth in the space available. But even with these limitations, they rather closely hedge the road to a true theory.

CLASSIFICATION OF HYPOTHESES OF PLANETARY GENESIS.

While this classification is intended only to include hypotheses of *planetary* genesis, leaving out the genesis of stars and other celestial bodies, it necessarily recognizes some considerations much broader than mere planetary genesis,

because these are a necessary part of the setting of the problem in hand. There are three orders of thought respecting the genesis of celestial organizations, in which the planetary element is not distinguishable from the rest.

Order I. Creational, Supernatural.—Once commonly styled “creation *ex nihilo*”; more strictly, the calling of the physical into being by mental act. This view is beyond naturalistic inquiry, and has not entered into this investigation.

Order II. Creational respecting “the beginning,” followed by development under “the laws of matter.”—In this view, which was distinctly dualistic, the “laws” were commonly regarded as *decrees* imposed on the material world. They were held to be rigid, inflexible, “without variation or shadow of turning,” in contrast to volitional action, regarded as the distinctive feature of the mental world. The creation of Order II was supernatural, as in Order I. After matter was called into being and endowed with physical and chemical properties, development began through the loss of energy by radiation, making the progress descensional rather than strictly evolutionary, in the full sense at present accepted.

As time went on, the creational factor was pushed backward or dropped entirely out of consideration, but the concept of a beginning largely remained in the background, the *a priori* mode of reasoning was retained, and progress was descensive by loss of heat. Commonly also, the doctrine of “the running down of the universe”—because of irrecoverable loss of heat—entered into the general philosophy and was held to signify the coming need of a new beginning. This later phase has thus largely been of the same order as the earlier, except for its larger reservations and its silence.

Order III. Indefinite cyclic evolution.—In its strictly scientific form, this includes simply inferences from what is now passing, from available vestiges of what has taken place, and from the import of these regarding past, present, and future alike. As a matter of fact, various phases of philosophy mingle with it. The beginning of the cosmos is held to be beyond the reach of human penetration, at least at present. No real beginning is therefore assigned, nor real end predicted. It recognizes constructive as well as destructive processes, ascensive as well as descensive trends, endothermic as well as exothermic reactions. It recognizes that these are inextricably mixed in time of beginning and ending, and in duration, and that there is no definite pointing to a simultaneous start. On the contrary, it recognizes a series of cycles of ascent and descent stretching indeterminately backward and presumptively forward. There commonly goes with this interpretation, the view that the actuation, however interpreted, is *immanent* rather than external, and that it embraces the mental as well as the physical. Here this view, in its turn, faces the unsolved riddle of the ulterior relationships of the mental and the physical worlds.

Under the broad mantle of these three orders of thought, specific views have been developed which differ in essentials about as biological genera do, as also, in minor features, about as species and varieties do. These fall into two divisions: (1) those which postulate that the sun and planets arose together as products of a common process, and (2) those which hold that the sun arose from some stellar process, while the planets arose from some later process as much their own as was the stellar process the mothering of the stars.

DIVISION I. HYPOTHESES WHICH HOLD THAT THE SUN AND THE PLANETS
 AROSE FROM A COMMON FORMATIVE PROCESS.

Genus A.—Creational, supernatural, as defined under Order I. The common view of the earlier centuries; not included in the present naturalistic inquiry.

Genus B.—Supernaturally creational in remote genesis; development afterward under "the laws of matter." Assigns rotation to shrinkage simply. Main cause of development assigned to loss of heat; separation of planetary matter assigned to centrifugal action. Type, the Kantian hypothesis. Found deficient in meeting the requirements indicated under sections 9 to 15 sketched above. More specific comments given under the next genus, which is dynamically similar.

Genus C.—No postulate as to ulterior origin. Start made from the assumption of a hot rotating nebula of vast dimensions, embracing the material of the solar system; development actuated by radiation leading to increasing rotation; separation of planetary matter assigned to centrifugal action. Type, the Laplacian hypothesis.

The graver objections grow out of requirements 9 to 16. Briefly some of the more vital may be resummarized here since the view, under the general name of nebular hypothesis, still has a large following notwithstanding the gravity of the objections to it: (1) The sun's rotation is far too slow to set off planetary matter by rotation; (2) the revolutional planes of the planets should be closely identical with the rotational plane of the sun, whereas they are oblique; (3) if the assumed nebula were restored by appropriately expanding the present solar system to the full extent permitted by its moment of momentum, contraction would not set off a ring or bunch by centrifugal action until the nebula had shrunk within the orbit of Mercury (Moulton); (4) the relatively small masses of the planets, ranging individually from one-thousandth to one-millionth, and amounting all together to less than one-seventh of 1 per cent of the whole, carry 98 per cent of the moment of momentum, while the sun, embracing 699/700 of the mass, carries only 2 per cent of the moment of momentum. Some of the individual ratios present even more striking inconsistencies from the point of view of systematic centrifugal separation.

The following views, classed as species, have been built upon the foregoing genetic postulates:

Species 1.—Separation by gaseous rings. The specific form of the Laplacian hypothesis. If the kinetic theory of gases is true—and it is now regarded as fully established—rings of gaseous matter of the assigned mass and dimensions could not be held together (Chamberlin, Jour. Geol., V (1897), 653–684). Even if the rings could be formed and maintained, grave difficulties would arise in their collection into planets (Moulton, Astrophys. Journ. (1900), 103–130).

Species 2.—The nebula a swarm of meteorites, whose mechanical action is regarded as quasi-gaseous (Lockyer, Darwin). So far as planetary formation is concerned, the generic difficulties already cited apply to quasi-gaseous meteoritic aggregations much as they do to true gases. (Special difficulties are discussed in Year Book No. 3, 1904–5, 195–208.)

Species 3.—Formation of planets assigned to individual infalls of scattered meteorites. An old and practically abandoned theory, based on the present infall of meteorites. It naïvely assumed the existence of the planets as a condition of their own formation. The masses of the planets are somewhat

increased by the infall of meteorites but *this is at the expense of the revolutionary competency* of the planets which the infall reduces. If carried far enough, meteoritic impacts would destroy the planetary system. They are therefore regarded as planet-killers, in their little way, rather than planet-formers. See requirements 1 to 6 ante.

Species 4.—Fission by rotation (Darwin). It is not claimed that fission is applicable to the planetary system as a whole or to those of the planets which have several satellites, but it has been urged as the mode of separation of the moon from the earth. The mathematical investigation of Moulton (Carnegie Inst., Wash., Pub. 107, 1909, 125-160) brings out the fact that the degree of contraction required to give rise to fission, in the manner postulated, would involve a density quite unassignable to such matter as forms the earth and moon.

CONCLUSIONS REGARDING DIVISION I.

The planets have such high endowments of revolutionary energy and moment of momentum, relative to the sun, that they are not believed to be the products of a simple evolutionary separation of a common original mass, whether that mass were chaotic (Kant), nebulous (Laplace), meteoritic (Lockyer), or otherwise. On the contrary, the characteristics listed as requirements seem to show that the sun, on the one hand, and the family of planets on the other, had diverse origins, the planets arising from some process of a conjoint nature by which great revolutionary energy and moment of momentum was given them, though their individual as well as their combined masses are very small, while the sun was left with great mass, low rotational energy and low moment of momentum. The assumption that the planets are mere by-products of stellar evolution seems to be untenable.

The place of the following genus in the classification is uncertain; the process postulated may be regarded as a part of a general evolution including sun and planets, or as a special process coming into action after the sun was formed. Certain phases of Species 3, Genus C, should perhaps be placed here, but the dominant phase of that type made the sun the chief target of the meteorites, and the maintenance of solar heat was at one time assigned to meteoric infall.

Genus D.—The formation of planets from foreign matter. To this genus are assigned all forms of aggregation or capture of bodies entering the sun's sphere of control from without. It is assumed that all such bodies would enter the sphere of control of the sun with courses and velocities similar to those of the stars in the outer environment of the sun, that is, courses diverse in direction, with mean velocities 20 to 30 miles (30 to 50 km.) per second relative to the sun. A study of the velocities of comets and meteorites has made it clear that there is now no medium of resistance of any moment within the sun's sphere of control, except that of the recognized bodies of the concurrent and discordant systems previously noted. This resistance is so slight, on the average, that foreign invaders would normally pass through the sun's sphere of control and go on their way. Such bodies can be supposed to be captured only rarely. The crucial naturalistic test is covered under requirements 1 to 7. The planets do not retain, in any detectable degree, the dynamical traits that should betray such a foreign origin, and a domestication into perfect resemblance to the concurrent planetary family seems out of the question.

DIVISION II. HYPOTHESES THAT ASSIGN THE GENESIS OF THE PLANETS
TO CONJOINT ACTION.

While the hypotheses of this group agree with those of Division I in holding that the planets are the offspring of the sun, they assume that the birth of the planets was not a feature of the primitive formation of the sun, but took place at some later stage of its history. These theories hold that the sun had an encounter which threw a small part of its matter out into the planetary field where it was diverted into planetary courses by the partner in the encounter. In other words, the planets are *diæcious* or *bi-parental* products. Efforts to find a cause of formation of planets in collision must be classified here, though views of this type have scarcely had a recognizable following. The Division rests almost wholly on the possibilities of dynamic encounter without bodily contact. (Astrophys. Jour., XIV, 1901, 17-40; Jour. Geol., IX, 1901, 369-393.)

Genus E.—The formation of planets by stellar collision. This genus is given a place here more on account of the efforts made to find a tenable theory than from any success attained. Difficulties, that seem insuperable, arise from the great violence with which stars and other large bodies collide and from the intense radial dispersion that follows. This form of dispersion is particularly unfavorable to reassemblage into revolutionary bodies. If the collision is eccentric, a rotational factor is introduced, but it must usually act at a notable angle to the plane of radial dispersion and so give a warp to the rotation trending toward helicoidal or spheroidal effects, rather than concentric concentration into a disk. Protracted efforts to find a working theory in a glancing collision have proved unsuccessful, and all efforts in the line of bodily collision are believed to be futile.

Genus F.—Genesis by dynamic encounter, in other words, the interpenetration and cooperation of the spheres of gravitation of approaching bodies; bi-parental genesis through dynamic encounter; planetary constituents sent forth from the sun into concurrent orbital courses—partly bunched, partly scattered—later gathered into planets.

These factors are regarded as basal and form the generic characteristics of the planetesimal hypothesis; its specific characteristics, to be noted later, lie in the *eruption* of the solar matter into nuclei and planetesimals which follow a specific line of evolution into planets.

Under this genus, three divisions in respect to the *source* of the interacting spheres of gravitation are recognized as *sub-genera*.

Sub-genus a.—Gravity spheres surrounding single stars, or equivalent bodies. This has been the working basis for the specific theories of planetary genesis listed below.

Sub-genus b.—The grouped attractions of a dominant part of a star cluster or its equivalent. This is not assumed to be effective except in the outer portion of the domain of the sun where its control is feeble. It is held competent to give slight diversions to projections from the sun; and hence very elliptical orbits, e. g., those of comets and meteorites (see Genus G). It is held incompetent to form planets.

Sub-genus c.—The coordinated attractions of many stars on the borders of great clusters, particularly the galaxy. Not applicable to the formation of the solar planets but perhaps an agency in the formation of the extra-galactic nebulae, and hence perhaps serviceable to planetary studies by way of analogy.

Under *Sub-genus a* there are three subdivisions in respect to *the path pursued by the passing star*: (1) The star may pass wholly outside the planetary field, acting on the ejected material wholly from without, the sun and star pulling in opposite directions and at large angles; (2) the star may pass between the sun and the planetary field, acting on the ejected material mainly from within and *in concurrence with the sun*, in so far as the projected matter is shot beyond the star. (Unless the star is very small relative to the sun, so close an approach is liable to be seriously disruptive and ill-fitted for the formation of planets of the meager masses under consideration.) And (3) the star may cut through the midst of the planetary field, acting on the ejected material partly from without in antagonism to the sun, and partly from within, in concurrence with it.

The taboo.—All specific theories under this genus had to face the fact that the assigned planetary matter was orbital, not gaseous or quasi-gaseous, and before acceptable hypotheses could be framed it was necessary to show that *aggregation from these orbital courses could and would give rise to forward rotations*, for it had been the standard doctrine for half a century that such aggregation would normally give *retrograde rotations*. Investigation, however, showed not only that the gathering of planetesimals and satellitesimals into their appropriate nuclei would usually give forward rotations, but that such ingathering was better adapted to give the varied rotational requirements of the case than aggregation from a gaseous state. This gave the genus a place among working hypotheses. (Year Book No. 3, 1904, 226-228.)

Species 1.—*The erupto-tidal form of the planetesimal hypothesis; projection of the planetary material assigned mainly to the eruptive power of the sun, but only with sufficient effect when stimulated, supplemented, and directed by the tidal influence of a passing star (or its equivalent); revolution of ejected nuclei and planetesimals assigned to the direct attraction of the passing star as it moves forward; rotation and many other features of planets assigned, in part, to eruptive effects and, in part, to mode of infall of planetesimals.*

There are sub-species and varieties under this species, some of which have been fairly well worked out, while others still remain in the trial list (see later).

The concurrent revolutions and the disk form of the planetary system (Requirements 1-7) are thought to be met successfully by the effects that followed the passage of a star in a plane somewhat oblique to the plane of the sun's rotation; the formation of the nuclei and planetesimals, and primary rotations, are believed to be natural products of the postulated eruptions; the small sizes of the ejections and the great distances to which they were projected follow the analogy of observed solar eruptions, but it is believed to have required the concentrating effects of the tidal compress-belt and conal out-drafts of a passing star to give effects of the planetary order. The revolutions are thought to be accounted for by the tangential component of the star's attraction as the nuclei and planetesimals were shot near it; the high values of their revolutionary energy and moment of momentum are natural consequences of such action. The belches of solar eruption are held to have given nuclei adequate to meet the requirements of effective collecting centers, while the common points of deviation led to nodes that favored aggregating, so that all its processes were inevitable under the conditions postulated. It is confidently believed that all the fundamental requirements of planetary genesis are met by this cooperative action on the part of a passing body and an

eruptive sun, and by the mechanical consequences that would necessarily follow such interaction.

Species 2.—*The tidal theory of Jeans* (*Mem. Roy. Soc. Astr.* (1917), 1-48). So far as applicable to planetary genesis, closely analogous to the preceding erupto-tidal theory, except that the sun's eruptivity is left out of consideration and the derivation of planets from the sun assigned to tidal effects alone. The theory is founded on dynamic encounter and other basal tenets of Genus F, but closer approach and more intense tidal action are required than in Species 1, because much of the dispersal referred by that to eruptive forces must be effected by tidal action alone. This closer approach involves danger of loss to the cooperating bodies, and leaves less room for the deployment of the planetary system. As set forth, the considerations are largely abstract and the postulates are disincumbered of concrete entanglements. They relate more to stars than to planetary evolution. They are chiefly concerned with distortional, disruptional, and divisional effects arising from powerful tidal actions on stars of high eccentricities which became affected, in the course of the evolutions assigned them, by stages of instabilities and bifurcations. Stars of high stability and slightly oblate forms are scarcely considered, the study centering on highly oblate spheroids, prolate ellipsoids, pear-shaped and furrowed forms, leading on to fissioning. These states are quite remote from the condition of the sun, whose oblateness is very low and whose stability is very high. No feature of the sun is cited as implying past participation in profoundly disruptive or fissional action. It is of course conceded that the sun has made very small contributions of matter to form the planets.

The planetary part of the tidal theory of Jeans embraces two distinctive features: (1) It is claimed that a stream of solar matter poured forth from the sun at a certain stage of the assigned tidal action induced by an approaching body, this stream constituting the planetary matter, and (2) that this stream took on a bunched or knotty state.

The deployment of these claims lacks fulness and concreteness, so that the chief working difficulties are not easily made clear, except as a supplementary

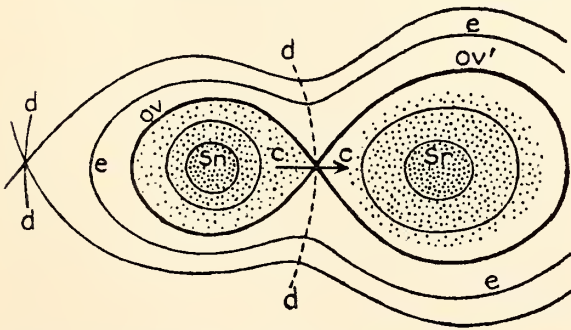


FIG. 1.—Relations of sun and star at the time of outpour indicated by arrow; e, e, e = equipotentials after Jeans, slightly extended; Sn = sun; Sr = star; Sr = 2 Sn; ov, ov' = ovoids; c, c' = cones; d-d = dividing line between spheres of control of Sn and Sr; dotted areas indicate surface of sun and star.

statement of the concrete conditions of action is made in which the spheres of control of the co-acting stars are used as a criterion. Taking as a basis for discussion Jeans's illustration of the conditions that gave rise to the postulated outpour (*loc. cit.*, p. 31), they may be abbreviated to the close approach to the sun of a star twice the sun's mass. It is definitely stated that such an outpour as postulated could only issue from the minor mass toward the major mass. Before these bodies approached one another, they were doubtless centers of undeformed or only slightly deformed spheres of control, these spheres being

perhaps separated and individualized by space under control of the star cluster to which they belonged. As they approached one another, their gravitative fields of course progressively penetrated one another, while the algebraic sun of these determined the progress of control which was always in favor of the more massive star. With every stage of approach the sphere of control of the star, the major body, encroached upon that of the sun, the minor body, until the encroachment led to the critical status, which was reached when the sun and star had mutually developed ovoidal equipotential surfaces with conal points directed toward one another, as shown in figure 1. Within these ovoidal surfaces, the fields of control were sharply defined, both for the sun and for the star; outside, they joined one another in depressions of the equipotential lines; still farther outward, they merged into a common field of control over which the star had dominant influence. The point to be specially noticed is that the sphere of control of the star then *filled the whole canopy as seen from the point of outpour*. The actual stage of outpour was reached when the equipotential ovoid of the sun had become suitably reduced to fit the sun's material surface, so that any further encroachment would cause outpour. At a little later stage, according to Jeans, similar action may or may not have arisen on the opposite side of the sun, but space forbids a discussion of this.

The critical stage of outpour brings into view also the embarrassments of the theory. The requirements of the case are that this outpour from the sun shall deploy into embryo planets *within the sun's sphere of control*. The distribution of the planets covers a circular tract whose radial breadth is now over 4,000,000,000 km. The acquisition of the appropriate revolutionary energy to sustain the material in planetary motion was also required. If the planetary field were not then what it is now—save for such modifications as meteoric accessions on the one hand, and radiation pressure on the other, and similar current influences might induce—adequate causes for any changes postulated must be added, and there is danger in this, for if the sun is supposed to have been larger than the orbit of Mercury, it probably must have participated in the revolution of the planetary matter and it would be almost certain to run counter to the demands of moment of momentum and be unable to shrink to the sun's present slow rotation, criteria that proved so fatal to the older shrinkage theories.

Now, referring to figure 1, it will be seen that the outpour of planetary matter from the sun *immediately entered the sphere of control of the star and was directed toward its center*. As the star was the more massive, it thenceforth had the advantage in *holding control*. How then could the outpoured matter form planets of the sun? It is unfortunate for the theory that a tidal outpour of this kind must always be from the less massive to the more massive star, and that if there is any propulsion, it is toward the center of the more massive star. There is the further disadvantage that this is near at hand because close approach is required. There is the still further disadvantage that this close approach draws the sphere of control of the star *over the whole canopy of the point of outpour* and leaves it no escape from directing its stream into the dominating control of the star. The big star strips the little star.

If escape from this is sought in the motions of the two bodies relative to one another, the first stage of effect of such motion would deflect the outpouring stream from its course, directly toward the star's center, into an oblique curved course, which would be *of the nature of an inrunning spiral* wholly

within the sphere of control of the star. This is very suggestive, relative to the associated nebular theory.

By consulting figure 1, it will be seen how difficult it is for the outpour to wholly avoid the encroaching and enveloping sphere of control of the star. The only line of escape is along the junction of the two spheres of control, *d-d*, at right angles to the axis of the tidal cone. Even along this line there is the second fatal contingency, long ago pointed out by Moulton, that of opposing pulls by sun and star, with the result that the projected matter will escape from both and go off into space on a course of its own.

To a realist a wholly decisive objection lies in the fact that *tidal action could not take place without great modification by eruptive action*, if the sun were eruptive in any such degree as it is now, or in any such degree as was probable all through its history as a sun, since high eruptive convection seems required to meet its radiation and its rotation. Long before such an entanglement due to very close approach could be reached, eruptive action, responsive to a much feebler tidal stimulus actuated from afar—little more than trigger and gun action—would have brought about eruptive projections in which the masses would have been small and the distances of projection great, as the case requires, and there would have been room for deployment.

Moreover, if the sun were highly eruptive and radiation pressure were effective, such a very close approach as that postulated in the illustrative case would almost certainly have endangered a disastrous explosion of the sun, for the approach was crowding hard upon the Roche limit. Very close approaches of stars more massive than the sun have always been regarded in this inquiry as inhibited from planetary genesis of the type under consideration. To the naturalistic inquirer, if the sun were eruptive, its eruptivity must be taken into account in any genetic action into which it entered.

The powerful forces concerned in the postulated tidal action embarrass the claim that the outpouring stream would gather into knots in the process of its extension. The outpour would need to be stretched some 4,000,000,000 km. to even cover the breadth of the planetary field. It must at once have begun to take its part in planetary motions, or it would have collapsed, and this motion would require continuous stretching without limit, for the innermost end must have moved eight times as fast as the outer end, if the genetic movements were like those of the present. The forces that control such movements are very powerful and any possible self-aggregative forces in the stream itself would be quite inconsequential (see requirements 8 and 9 ante).

Genus G.—*Multi-parental genesis by repeated feeble encounters in the outer field of the sun's sphere of control; only assignable as the source of bodies whose orbits are very elliptical, such as comets and meteorites.*

This hypothesis assumes (1) that the eruptive power of the sun, aided by radiation pressure, is competent, at not infrequent times, to project small portions of its substance into the outer reaches of its sphere of control and perhaps beyond; (2) that as the sun passes among stars and star clusters, its domain is penetrated by unequal attractions in diverse directions, components of which act transversely to the line of solar projection; (3) that while this tangential effect is small, it has the advantage of acting on the outshot mass during its slow approach to its aphelion, during its stop at aphelion, and during its slow start back to the sun, an advantage thought to be sufficient to give the mass a lateral diversion adequate to make it miss the sun's body on

its return and swing into a narrowly elliptical orbit. The distinguishing physical features of comets and meteorites are assigned largely to the incidental consequences of alternate exposure to the intensely cold conditions of aphelion and the intensely hot conditions of perihelion, together with the collisions to which their discordant courses specially expose them. Their spheres of control are very small when near the sun and quite large in aphelion (Year Book No. 19, 1920, 378-381). Special discordance is assignable only to the products of different eruptions, not to the products of single eruptions. This is not regarded as a planetary genus, but comets and meteorites are so intimately related to planetary formation that it is given a place here.

WORK IN ADVANCE.

If space had permitted, there would have been added a sketch of the working aspects which the inquiry now assumes. There would also have been a sketch of the recent detection and assemblage of a group of inconspicuous vestiges which seem to bear on important details of the planet-forming process. It is regarded as appropriate to the functions of this inquiry, not only to detect such residues of past actions as may elucidate the early history of the earth, but such intimations of lines of solution as may reduce the excessive labor of working out past planetary events by haphazard computations, unaided by forecasts deducible from naturalistic evidences.

HISTORY.

Rogers, Robert W., Madison, New Jersey. *Study of the problems of the history of Ancient Persia.*

The summer was spent in Oxford, London, and Paris, studying the problems of the history of Ancient Persia.

A survey has been completed of all the inscription material, Persian as well as cross-references in Assyrian and Babylonian original sources, for the entire period from Cyrus the Great to Alexander the Great. In this same period I examined afresh every allusion in the Greek and Roman historians original sources. This portion of the work is completed, and save for an end-to-end revision for the sake of unity of expression and form it is ready for publication.

I propose, if able to go to Europe next summer, to deal with the same thoroughness, in so far as materials offer or permit, with the earliest Median and Persian period. I have already assembled the necessary materials and have made a preliminary study of Zarathustra and his influence on Persian history.

There will then follow the co-ordination of the parts already written with that in still imperfect form, or unfinished, into a History of Ancient Persia, from the earliest times to Alexander the Great—all from original sources.

HISTORY OF SCIENCE.

Sarton, George, Cambridge, Massachusetts. *Associate in the history of science.* (For previous reports see Year Books Nos. 18–21.)

The present (sixth) report covers a period of only ten months, from September 1, 1923, to June 30, 1924.

1. *Introduction to the History and Philosophy of Science.*—The greatest part of my time is devoted to the preparation of this introduction. I have now reached the fifteenth century. Though a large amount of research remains to be done, I hope to be able to offer for publication, by the end of next winter, the part dealing with ancient and medieval science down to about the year 1500.

2. *The Publication of Isis.*—During the past year I have edited three numbers of *Isis*, forming the end of volume 5 (pp. 325–576) and the beginning of volume 6 (pp. 1–132). They contain 8 papers, 7 shorter communications, 63 reviews, and 557 bibliographic notes. Some of these notes have been contributed by A. K. Coomaraswamy (Boston), L. Guinet (Brussels), E. Kremers (Madison, Wisconsin), W. Libby (Pittsburgh), H. Metzger (Paris), K. Schoy (Essen) and H. Wieleitner (Augsburg).

The number of books and papers reaching the editor is increasing continually and their examination is consuming more and more time. The need of additional collaborators is becoming more urgent every day, especially of such as are near enough to confer frequently with the editor. I have been able to secure the constant collaboration of L. Guinet of Brussels, who will be the managing editor and remain in touch with the printers. The following scholars have kindly agreed to act as associate editors and advisers: C. H. Haskins, Harvard University, Cambridge, Massachusetts; R. C. Archibald, Brown University, Providence, Rhode Island; J. K. Wright,

American Geographical Society, New York. Besides, the editing of special departments has been intrusted to the following: Queries and Answers, to F. Barry, Columbia University, New York; Teaching and Personalia, to H. E. Barnes, Smith College, Northampton, Massachusetts; Obituaries, to F. E. Brasch, Department of Terrestrial Magnetism, Carnegie Institution, Washington, D. C.

3. *The History of Science Society*.—It is extremely gratifying to report the organization of this new scientific society, the purpose of which is to promote the study of the History of Science and more particularly to support the publication of *Isis* which has become its official organ. The society was actually founded in Boston on January 12, 1924. I take advantage of this opportunity to express my deep gratefulness to the men of science and scholars who have taken the initiative of this organization and have thus lifted from my shoulders a financial burden which was gradually crushing me. There is good reason to hope that the History of Science Society will exert a beneficial action upon the intellectual life of America, not simply in promoting sound scholarship but also in bringing together men of science and scholars. As was said in its first printed appeal: "The proposed society will be the first, on any large scale, to afford a common meeting ground for scientists, historians, and philosophers. Indeed the study of the history of science seems to provide the only feasible method for bridging the widening gap between the men of science on the one hand and the men of letters on the other." The rapid growth of the new society (more than 400 members were enrolled by July 1924) proves that its creation was opportune.¹

4. *The New Humanism*.—My efforts to explain the New Humanism and to organize the study of the History of Science are but two different aspects of the same activity. An elaborate account of the ideals of the New Humanism and of their relation to the more special investigations of the historian of science was published in *Isis*, vol. 6, 9-42, 1924.

5. *Lectures*.—I delivered at Harvard University a course of 38 lectures on the history of science in the eighteenth and nineteenth centuries. It was attended by sixteen students.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature*. (For previous reports see Year Books Nos. 11-21.)

During the past year the collation of the words used by Lydgate in his "Fall of Princes," with the material supplied by the Oxford Dictionary, has been brought down to the parts last issued of the latter, now nearing completion. The glossary is typewritten and only awaiting the appearance of further instalments of the Dictionary. The work of comparing the English text with the French original of 1409 is also going forward satisfactorily, and at the end of June 1924 had been carried down to the beginning of Book III, or, roughly, through about one-third of the text. This study of the main source of Lydgate's poem, printed together with notes relating to other questions of language and metre, will form a running commentary on the text and will be not only of considerable interest in itself but of value as an aid to further studies on the sources of "The Fall of Princes."

¹ More information on the History of Science Society will be found in *Isis*, vol. 6 and following, or may be obtained from the Secretary, Prof. D. E. Smith, Columbia University, New York.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-22.)

For the development of dynamical meteorology the most important event of this year has been the establishment of a complete circumpolar weather service. The importance of arriving at a service of this extent has been emphasized in previous annual reports, in which the "polar front" phenomena have been discussed (see especially Year Book No. 19). The weather charts, which can now be drawn every day, are approaching toward covering the entire northern hemisphere. This must fundamentally change the meteorologist's view of his problem. As long as his chart was limited he could look for the causes which lead to a change of the weather both inside and outside the frame of the chart; the problem was more or less an indeterminate one. Henceforth, on the contrary, he can look for them only *within the frame of his chart*, provided of course that it contains data both from the ground and from the higher levels. The problem is becoming a determinate one, at least inasmuch as it is of pure terrestrial character.

While the external conditions for progress are thus improving, internal work has at the same time made an important step forward. The aim of our work has always been to prepare the solution of the forecasting problem in its exact form, i. e., as a problem of hydro- and thermodynamics, and if possible ultimately to give this solution. The first direct attack upon the forecasting problem from this point of view was made by Sverdrup and Holtmark, see the annual report of Year Book No. 16 (1917). The attempt gave useful hints but no direct success. A renewed attempt has this year been made by J. Bjerknes, and at least with some success.

The comparison of the methods used in the two cases is instructive. Both concern weather situations in which a marked line of discontinuity passes over the chart. The method used in the first attempt was characterized by a smoothing out of the discontinuity, for arriving at a situation with corresponding continuous conditions. But after that time, through the investigations of the last 5 to 6 years, the importance of the atmospheric discontinuities has been fully recognized. As a consequence of this the opposite method was chosen. The discontinuity was retained and its properties utilized. Starting with the general equations of atmospheric discontinuities given by V. Bjerknes in his paper *Circular Vortex* (cf. Year Book No. 20), J. Bjerknes has derived a simple formula which permits calculation of the acceleration of the air masses on one side of the surface of discontinuity relatively to those on the other. The formula can be used for calculating future wind in cases when a sufficiently complete diagnosis of the atmospheric conditions on both sides of the surface is at hand. The method is exemplified upon a situation in the Alps, February 1, 1913, when the observations from the ground combined with registrations from mountain stations gave a very complete diagnosis. The paper by J. Bjerknes is now ready for print.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-22.)

For reasons stated in our report last year, we have continued our investigations of the constituents of the alfalfa plant. The results therein discussed concerned the isolation of certain basic substances found after the concentrated juice had been hydrolyzed. This work has been repeated upon juice which had not been subjected to hydrolysis and efforts were made to avoid as far as possible any decomposition of the complexes which might have yielded the substances already isolated. We have found that stachydrin and the new base, the picrate of which melts at 298°C ., are free in the juice; at least half of the arginine, but only a small proportion of the lysine, are free. In addition, we have established the presence in alfalfa juice of considerable asparagin, a little tyrosin and choline, and a very small amount of a purine allied to xanthine.

Our chief efforts have been devoted, however, to the development of methods of fractionation whereby the various groups of nitrogenous substances may be separated from each other. This is a prerequisite to the isolation of chemical individuals in pure form, but is necessarily slow. Details of the methods we have adopted have been published in two papers in the *Journal of Biological Chemistry*. It will suffice here to call attention to the use of mercuric acetate, sodium carbonate, and alcohol (Neuberg's reagent), which we have found to be a valuable precipitant for the amino-acids and bases. By its use a fraction was obtained which contained 26 per cent of the total nitrogen, 67 per cent of the amide nitrogen, and 45 per cent of the amino nitrogen of the unhydrolyzed alfalfa juice. This illustrates the value of the reagent as a means of concentrating amides and amino-acids.

Although we have endeavored to account for the nitrogen converted into ammonia by boiling with acid by the isolation of definite amides, we have succeeded in obtaining asparagin in an amount equivalent to only 35.7 per cent of the total amide nitrogen. Further research will be necessary to establish whether other amides also are present.

The preliminary work upon methods of fractionation, both upon hydrolyzed and unhydrolyzed alfalfa juice, has indicated the presence of notable proportions of substances having the solubility relations of the dicarboxylic amino-acids, of arginine, and of lysine. Work, designed to shed further light upon the nature of these substances, is at present in progress. We likewise are accumulating a quantity of the new base sufficient for its identification.

Very little definite information can be found in the literature regarding the nature of the substances precipitated from plant extracts by basic lead acetate. A study of these substances is being carried on.

Dr. A. C. Chibnall has continued his investigations of proteins of leaves of spinach and also those of the alfalfa plant. By employing methods mentioned in our report for last year it has been found possible to separate the vacuole fluid from the cytoplasm and cell-wall material. The leaves are immersed for a few minutes in ether, which causes plasmolysis, and subjected to pressure in a Buchner press. The vacuole fluid is readily squeezed out, but, as the cell-

walls remain unruptured, the cytoplasm is retained within the cells. This vacuole fluid contains only traces of protein, which can be separated either by heat-coagulation or by allowing the acidified fluid to stand 24 hours. This protein is soluble in weak alkali, but insoluble in weak or strong acid. The heat-coagulated sample contained N, ash-free, 13.96 per cent. On hydrolysis it gave the following distribution of N:

	Per cent of total N.
Amide N.....	7.98
Humin N.....	2.24
Basic N.....	20.35
Monoamino N (diff.).....	69.43

After removal of the vacuole fluid the cytoplasm can be dispersed into colloidal solution by grinding the press residues with water. The green solution so obtained is filtered through paper pulp. All the green chloroplast material in sufficiently coarse suspension to be visible under the microscope is held back, the filtrate being a pale yellow-brown color. The addition of the requisite amount of acid to this filtrate causes a protein to separate sharply at its isoelectric point. This protein—purified by resolution in weak alkali and a second filtration through paper pulp—is completely soluble in the least excess of either acid or alkali. It contains N, ash-free, 16.25 per cent. Molisch's and Tollen's test are negative, showing that the preparation contains no carbohydrate impurity. On hydrolysis it gives:

	Per cent of total N.	Per cent of total protein.
Amide N.....	6.88	1.12
Humin N.....	1.19	0.19
Basic N.....	24.80	4.03
Monoamino N (diff.).....	67.13	10.91
		16.25

From its mode of preparation there seems no doubt that this protein is derived from the cell-cytoplasm, and as such its isolation in a state of purity is of great importance in the study of the chemistry of the living cell. Investigations on similar lines are in progress with the leaves of the alfalfa plant.

Much remains to be learned concerning the part played in nutrition by the various amino-acids which proteins yield on digestion. As a preliminary to further studies in this field, much time has been devoted to preparing large quantities of pure amino-acids which can be used in feeding experiments. In this connection a study has been made of methods by which the best yields of the several amino-acids can be obtained. A modification of Dakin's method has been developed which can be applied on a large scale and avoids some of the difficulties encountered in using this otherwise valuable process. In the course of this work we succeeded in demonstrating that the protein

edestin contains no oxyglutaminic acid. As our feeding experiments have proved that edestin furnishes all of the amino-acids needed for growth, we can now add oxyglutaminic acid to the list of non-essential amino-acids.

Attention has been directed in earlier reports to the advantage of using a preparation of vitamine B which does not give protein reactions. Our preliminary observations indicated that it sufficed, in considerably smaller doses than that of desiccated yeast, as a source of vitamine B. We have now found that, as for dried yeast, the dosage of the concentrate in terms of the absolute requirement increases with increments in size of the animals. Whereas 10 mg. per day of the yeast fraction was insufficient for a 100 gm. rat, 20 mg. usually sufficed to permit good growth. It, in turn, is insufficient to promote growth at a normal rate in larger rats and failed entirely to permit even maintenance of animals of nearly mature size (e. g., 250 gm.). When the vitamine dosage was increased, or when an initial dose of 40 mg. per day of the same product was continued, rats grew at a normal rate to 300 gm. or larger. Broadly speaking, the dosage seems to bear some relation to the amount of active tissues of the animal. This may explain why the dose per unit of body-weight is somewhat smaller for the large rat than for the young. These satisfactory tests of this protein-free vitamine-B concentrate confirm our expectation of its usefulness for nutrition experiments throughout all stages of growth.

Our experiments show that when the smaller doses are fed to larger animals a decline in weight ensues; with intermediate doses there may be maintenance at various levels of body-weight; with the larger vitamine-B intake for the smaller animals growth ensues. The organic part of the comparatively crude concentrate that we have used constituted not more than 0.4 per cent of the average food-intake of our experimental animals.

Several years ago we demonstrated that animals can grow to adult size without receiving more than traces of preformed fat in the diet. To what extent preformed carbohydrates are essential has remained to be ascertained. It is generally understood that the ability of the organism to metabolize fats is in some way dependent upon an adequate supply of physiologically available carbohydrate. Without the latter, ketosis may ensue. The effect of carbohydrate in preventing or abolishing ketonemia is believed to be the result of definite chemical reactions in the tissues. There are experimental proofs that sugar can arise endogenously from amino-acids in protein breakdown as well as through glycogenolysis. The glycerol radical of the fats is a further potential source of glucose, or at least of antiketogenic substances. Whether these purely endogenous precursors will suffice to permit a normal metabolism has not been demonstrated.

Our experiments show a surprising capacity in rats to grow to adult size at a normal rate on rations containing not more than traces of carbohydrate. The foods contained various proteins and fats in widely different proportions along with a suitable inorganic salt mixture and sources of vitamines A and B. Our experiments suggest that in as far as carbohydrate is required for the intermediary metabolism, particularly for the metabolism of fats and the development of energy in muscular contraction, it can be furnished endogenously throughout the period of growth to adult size, even when more than half of the energy intake is supplied in the form of fat. The glycogen content of some of the animals was by no means negligible. The absence of pre-

formed carbohydrate did not prevent or alter the prompt recovery of rats which had previously declined on foods containing no vitamine A, when this factor was again supplied. Also, when the organic foods consisted essentially of protein and fatty acids growth occurred. The addition of glycerol showed no advantage in these cases.

Reference has already been made in an earlier report to the striking hypertrophy of the kidneys that occurs when proteins constitute a large part of the calorie intake of rats. The apparent absence of histological features indicating any inflammatory or degenerative changes is contrary to widespread clinical impression of the effect of "high-protein" dietaries. The importance of the subject has accordingly led us to extend our experiments in this field, with the cooperation of Professor Park and Professor Winternitz, of the Yale University School of Medicine, who are making the macroscopic and microscopic postmortem observations. "Functional hypertrophies" of the kidneys, amounting to increments of 50 per cent or more, are developed within a period of two weeks in young rats.

Tests in progress indicate that rats can continue to grow for many weeks without apparent hypertrophy of the kidneys on diets containing 17 per cent of inorganic constituents, a third of which was sodium chloride. On foods containing 22 per cent of urea, in addition to the usual content of 18 per cent of protein, animals likewise have made considerable gains at normal rates.

The success of the varied types of experiments on diets extremely unlike those of everyday experience is presumably attributable to the fact, that so long as the "law of minimum" is not violated, surprisingly large variations in the quantitative make-up of the diet may apparently be tolerated.

In a new series of approximately 4,000 of our rats, 493 on diets containing little if any of the vitamine A were under observation 20 days or longer. Among the latter ophthalmia was actually recognized in 297, or 60 per cent. This is even greater than the percentage incidence (50 per cent) in an earlier group of rats reported by us. When the affected animals were grouped with reference to the relative "purity" of the substances used in preparing the food mixtures, it was apparent that the characteristic eye disease appeared more promptly and frequently among rats living on the better purified foods than among those on the less thoroughly purified diets. In the group which received diets of the greatest degree of purity the incidence of ophthalmia was 82 per cent; hence our renewed experiences are contrary to the failures recently reported by Hejinian in producing ophthalmia in rats on "synthetic vitamine-A-free diets."

In collaboration with Professor Park and his associates in the Yale School of Medicine, the studies of the relations of diet to structural changes in the body, particularly those of the skeleton, have been continued. We are attempting to secure observations under conditions of carefully controlled or modified diet. There are manifold factors that play an important rôle in determining the quantitative and qualitative changes in a developing bone. To evaluate the relative importance of each of these without affecting the concomitant alterable factors has proved to be more difficult than was anticipated. We have already succeeded in formulating diets of purified food substances which lead to the development of either rachitic or osteoporotic changes in the bones. For example, when rats are fed on a mixture of the phosphorus-free protein, edestin, starch, a salt mixture demonstrably adequate

except with respect to its content of phosphorus, along with a small quantity of yeast fraction bearing vitamine B, rickets, well marked both clinically and histologically, develops within a month. This pathological condition can be averted by increasing the intake of phosphorus in the diet and by supplying a source of the so-called antirachitic vitamine. The experience which we have already gained tends to substantiate the current view that the antirachitic vitamine (sometimes called vitamine D or factor X) is not identical with the vitamine A, characteristic of milk fat and many green vegetables. The problems studied include: The comparative effects of deficiency in calcium and phosphorus respectively; the rôle of the calcium-phosphorus ratio in relation to the development of rickets; the influence of the reaction of the diet, i. e., the preponderance of acids or bases in the intake; the influence of the growth-factor on the development of rickets, i. e., the relation of the rate and extent of growth upon the readiness with which the bone abnormalities develop; the influence of varying planes of nutrition with respect to protein and nonprotein factors on the rate of development of rickets; the stability of the antirachitic substances. It is inadvisable to attempt to formulate at this time any far-reaching generalizations from the extensive data already collected.

Mr. K. E. Mason has continued in Professor Harrison's laboratory at Yale University his studies on our rats with respect to changes in the gonads of the male under various conditions of feeding. Using our "standard" casein diet, which consists of casein 18 per cent, salt-mixture 4 per cent, starch 54 per cent, lard 15 per cent, butter-fat 9 per cent, plus 0.2 gram yeast daily—a food which has proved adequate for growth but not for reproduction—he has found that there is a definite degeneration of the germ-cells of the testes of rats reared from weaning on the "standard" casein diet. The sperm and spermatids are first affected, and in later stages the entire germinal epithelium, with the exception of the Sertoli cells. This degeneration is very evident histologically, usually after a period of 60 to 100 days on the diet, the individual rats showing a rather wide variation. Ordinary mixed diet has not restored sterile rats to a normal condition after periods of 100 days. Such rats show no improvement over those continued on the "standard" diet for a similar period. Sexually mature rats when maintained on the "standard" casein diet for 50 days show no evident departure from the normal histological condition. The later stages up to 180 days have not yet been studied microscopically.

PALÆOGRAPHY.

Lowe, E. A., Oxford, England. *Associate in palæography*. (For previous reports see Year Books 9-16, 19-22.)

As the investigation of uncial and half-uncial manuscripts advances it becomes increasingly clear that a history of these very ancient types of writing, in which the question of their origin, extent, duration, and peculiarities are adequately treated, can not be written before considerable preliminary researches have been completed. And it becomes even clearer that the most useful approach to the solution of these problems lies in the intensive study of certain individual centers.

In a previous report, mention was made of the palæographical importance of Lyons—an ancient city that still possessed manuscripts written there over a thousand years ago. Lyons as a center merited a separate study and it was planned to devote special attention to it. The invitation from the authorities of the Lyons Library, to which reference was made in the last report, was therefore gladly accepted. The library was visited in September and October of last year, and again in January of this year. The material gathered was embodied in a monograph during the winter months and sent to Lyons in April. It is just going through the first stages of the press and will appear before the year is out. It is entitled *Codices Lugdunenses Antiquissimi*. The letter press is illustrated by 37 colotype plates and two half-tones. The facsimiles are drawn from 23 manuscripts preserved in the libraries of Lyons, Paris, Cambridge, and Berlin. Public acknowledgment is gratefully made to the heads of these libraries, especially to R. Cantinelli, former director of the Lyons collection, and to H. Joly, his successor.

Thanks to the work upon the Lyons manuscripts, it was possible to verify a theory long entertained as to the connection of the Codex Bezae with Lyons. Palæographical evidence fully establishing the relationship was given in an article entitled *The Codex Bezae and Lyons*, published with two plates in the April issue of the Journal of Theological Studies. The textural importance of this most puzzling of Biblical manuscripts is such that any new light upon it is of interest to scholars.

The autumn months of last year were taken up with a paper entitled *A Handlist of Half-uncial Manuscripts*, to appear in the Miscellanea Ehrle. Proofs have already reached me, and publication will be in October of the present year. The study entitled *The Palæography of the Bobbio Missal* has also been seen through the press and its early appearance is promised. Reviews of Lindsay's *Palæographia Latina II* have appeared in the Classical Review and Revue Bénédictine. Altogether it is a pleasure to state that thanks to the new facilities afforded by the generosity of the Institution, this has been by far the most fruitful year since 1914.

The collection of palæographical negatives has been considerably extended, the following important libraries having been put under contribution: Berne, Zurich, St. Gall, Verona, Milan, Turin, Bologna, and Florence. For most of the Italian Libraries I had the assistance of the expert photographer of the Vatican Library. As evidence of the esteem in which the Carnegie Collection of palæographical negatives is held, it may be mentioned that the curators of the Bodleian Library have ordered prints of these negatives to be made for the use of the Bodleian readers.

PALÆONTOLOGY.

Chaney, Ralph W., Berkeley, California. *Research Associate in Palæobotany.*
(For previous reports see Year Books Nos. 21, 22.)

Data are gradually being accumulated which tend to fill in the lower Tertiary section on the coast of Washington and Oregon and to relate it to the better-known sections in the Great Basin. A flora collected by Ralph B. Stewart, of the University of California, is associated with a Tejon fauna which indicates its Eocene age; another flora sent in by students at the University of Washington has as one of its most characteristic species a leaf which has been found associated with an invertebrate fauna of Oligocene age. The Goshen flora of Oregon is associated with Oligocene invertebrates and appears to contain at least one species which is closely related to a member of the Lower Clarno flora of the John Day Basin.

A continued study of the John Day floras has emphasized their resemblance to certain of the forests now living in the western United States. The relationship of the Bridge Creek flora to the modern redwood forest has been quantitatively established by means of a count of over 20,000 fossil specimens in the Bridge Creek shales and some 8,000 specimens in the contemporary stream deposits in the redwood forest at Muir Woods, California. The four dominant species of the fossil flora, *Sequoia langsdorffii*, *Alnus carpinoides*, *Quercus consimilis*, and *Umbellularia* sp., make up 86.44 per cent of the total of the specimens counted at the type locality on Bridge Creek; the closely related living species, *Sequoia sempervirens*, *Alnus rubra*, *Quercus densiflora*, and *Umbellularia californica*, make up 85.44 per cent of the total of the specimens counted in the stream deposits at Muir Woods. Certain fossil species which are found to be rare, such as *Rosa hilliae*, *Corylus macquarryi*, and *Cornus* sp., are sparsely represented by the corresponding species of these genera in the contemporary stream deposits. By determining the correlation values of leaf and tree numbers in the Muir Woods forest, it has been possible through the use of a prediction formula to determine rather accurately the relative and actual number of trees of the more abundant species which made up the forest during the Bridge Creek epoch. Some indication of the physical changes which have occurred in central Oregon since the middle of the Tertiary is suggested by the abundance in the Bridge Creek flora of the four fossil species whose modern equivalents are so characteristic of the humid coast of California to-day.

The Mascall flora occurs in diatomaceous shales which are stratigraphically above the Bridge Creek shales, with the thick series of Columbia lavas between them. It contains a number of characteristic Bridge Creek species, but its general facies is so different as to make the two floras easily distinguishable. Recent studies of the Mascall flora indicate its relationship to the forest now living on the borders of the redwoods, where greater exposure and a lower amount of soil moisture result in a more xerophytic assemblage. Here the California black oak (*Quercus kelloggii*), the madroña (*Arbutus menziesii*), the California buckeye (*Æsculus californica*), and others are conspicuous members, and the presence of related species of these genera in the Mascall flora suggests that it is of the redwood border type. It seems probable that the change from the Bridge Creek to the Mascall flora in the John Day Basin may best be

interpreted as representing not so much a change in the floras themselves as a change in their distribution, due in large part to diminished rainfall. Studies of the distribution of modern forest trees with relation to sites of sedimentation indicate that the only ones likely to be represented by considerable numbers of leaves and fruits in the sedimentary record are those which are growing near the basins of deposition. It may be supposed that, if the rainfall in the Redwood Belt were cut down at the present time, many of the redwoods, alders, and laurels would die out and the tree species formerly restricted to the exposed ridges and other border areas would advance to the stream borders and take their places. In this position many of their leaves and fruits would mingle with the sediments in the basins of deposition, and instead of a large representation of the remains of redwood, alder, tan-oak, and laurel, there would be a considerable number of the leaves and fruits of the black oak, madroña, and California buckeye. Some such change in climate and distribution appears to have taken place in central Oregon during the Tertiary, resulting in the change from a typical redwood forest in the Upper Oligocene to a forest containing a relatively small number of redwoods and redwood associates, and a larger number of black oaks and other border forms in the Miocene.

During the 1924 field season, Frederick H. Frost, of the University of California, and Leo G. Hertlein, of Stanford University, acted as field assistants.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia.
Report on work done on the Pleistocene epoch and its vertebrate fossils.
(For previous reports see Year Books Nos. 11-22.)

Since the writer's report on his work was made in September 1923, a considerable part of his time has been taken up in seeing through the press his book on *The Pleistocene of the Middle Region of North America and its Vertebrated Animals*. The region treated is that between the Mississippi River and the Great Basin Region, Idaho, and northward.

A work on the western region of North America is in an advanced stage of preparation and it is hoped will soon be completed.

Merriam, John C. and Associates. *Continuation of palaeontological researches.*
(For previous reports see Year Books Nos. 20-22.)

The investigations of the past year represent extension of work on problems initiated in previous years. The plan and purpose of these investigations has been discussed in the Year Book reports of 1921, 1922, and 1923.

The monographic study of the extraordinary series of geological formations and faunas of the John Day region of eastern Oregon was continued during the field season of 1924 with the use of preliminary copies of topographic maps kindly furnished by the Topographic Branch of the U. S. Geological Survey. The Twickenham topographic sheet, including the largest areas of the major formations of the John Day region, was completed in the past field season by the topographic parties of the U. S. Geological Survey so that the entire map will be available for use in the season of 1925. A topographic map of a supplementary area covering the type localities of two additional formations is planned for the coming season. These maps will give for the first time an opportunity to determine accurately the relations of the typical sequence of formations in the John Day region.

The geological mapping of the northern part of the Twickenham topographic sheet and the southern portion of the region immediately to the north was

advanced rapidly by Dr. John P. Buwalda in the latter part of the season of 1923. This work was extended and verified by a large party in the summer of 1924. The mapping of this region has proved extraordinarily interesting and, as was expected, has brought out many points of importance in the geological succession not previously recognized in the absence of maps.

The mapping of palaeontological zones of formations of the John Day region was continued in the summer of 1924 by Dr. Chester Stock and Mr. E. L. Furlong, of the University of California, assisted by a group of advanced students in geology and palaeontology. Dr. Ralph W. Chaney, of the Carnegie Institution, assisted by Mr. Frederick H. Frost, Fellow of the Institution, with the cooperation of graduate students extended the study of the plants through the major formations and secured large collections. A more extended report of this palaeobotanical work is given in Dr. Chaney's report on page 292.

The study of the Pleistocene faunas of California, including the series of monographs on the fauna of Rancho La Brea and of the study of the asphalt from McKittrick, California, was continued by Dr. Chester Stock and Mr. E. L. Furlong of the University of California. The work of the present year has involved largely the preparation, measurement, and description of important material, together with the preparation of several large papers for publication.

The work of Mr. Remington Kellogg on the study of the marine mammals has been continued in accordance with the lines laid down in previous years. It has resulted in a series of extremely interesting and important studies, two of which have been published. Five are ready for publication, and three are nearing the stage of completion.

Special statements by Dr. Stock and Mr. Furlong relative to these researches are as follows:

Research activities in mammalian palaeontology have progressed along several lines as follows:

1. In pursuance of the program of palaeontological and geological investigations to be conducted in the John Day region, a party consisting of Chester Stock, E. L. Furlong and three students of the University of California entered the John Day basin during the summer of this year and spent five weeks in that area. Two base camps were established during that time, these being situated in areas mapped topographically by the U. S. topographers and geologically by Dr. J. P. Buwalda. The following results were obtained:

- a. Systematic collection of vertebrate fossils in the John Day deposits and the allocation of all material found with reference to the topographic map and the geologic horizons. The principal collections were made in the green-colored beds, presumably of the middle John Day, as exposed north of Clarno Ferry along the John Day River, in the Cove near Pine Creek southwest of Fossil, Oregon, and in buff- and green-colored beds exposed along Bridge Creek. In the areas cited the Clarno and John Day sections as exposed were examined, but only in those deposits indicated where vertebrates were found. In the course of this work several new fossil plant localities were discovered in the Upper Clarno beds.

- b. Collections of additional later Tertiary vertebrates from the Mascall Middle Miocene beds and the Rattlesnake Lower Pliocene beds of the John Day Basin, near Dayville, Oregon. The discovery by Mr. E. L. Furlong of horse remains in beds presumably overlying the rhyolite in the Rattlesnake. Heretofore little palaeontologic material was known from this horizon.

- c. Detailed survey of the geologic sections in which vertebrates occur with a view to determining the association of mammalian types, the conditions

under which their remains have accumulated, and their zonal arrangement within a stratigraphic unit.

d. Cooperation with Dr. R. W. Chaney and Dr. J. P. Buwalda in the study of the stratigraphic, floral, and faunal succession in the Clarno-John Day sections near Clarno Ferry and on Bridge Creek.

The palaeontological materials collected during the past summer have been sent to the University of California where they will be prepared in the laboratories of the Museum of Palaeontology.

2. Investigation of the Pleistocene deposits at Fossil Lake and vicinity in south-central Oregon. Work in this region has resulted in the collection of additional remains of Pleistocene mammals and birds from this important horizon. Valuable material of the horse, *Equus pacificus*, was secured, to be used in the study of the species *E. occidentalis* of Rancho La Brea.

3. Study of the later Tertiary beds and faunas of the Singatse Range and the Pine Grove Mountains south of Yerington, Nevada. Here occur mammal-bearing beds ranging in age from Esmeralda Upper Miocene to Lahontan Pleistocene, and of particular interest are Pliocene deposits furnishing new mammalian types.

4. During the spring of 1924 in cooperation with the Los Angeles Museum an occurrence of ancient human remains in Los Angeles was investigated and reported upon. (*A recent discovery of ancient human remains in Los Angeles, California*, C. Stock, Science, n. s., vol. LX, pp. 2-5, 1924.)

5. Proof of the memoir on the ground sloth was read, as well as that of the paper on the short-faced bears. A restoration of the head of the bear, *Arctotherium*, has been prepared by Mr. Charles R. Knight, under the direction of Dr. Merriam and Chester Stock.

6. Investigations relating to the families of Felidae and Equidae occurring at Rancho La Brea have progressed with accumulation of considerable data regarding the variability of the specific types within these groups. Memoirs dealing with these families are being prepared by Mr. John L. Ridgway.

The following account of work on fossil marine mammals is quoted from a statement of Mr. Remington Kellogg:

Critical study of fossil pelagic mammals from a number of North American Tertiary formations has occupied part of my time during the past year or so. Of these, the largest faunas have been obtained from the Calvert and St. Marys formations of Maryland, the Edisto formation of the Ashley River region of South Carolina, the Bone Valley Land Pebble Phosphate formation of Florida, and the Kirkwood formation of New Jersey. During this period, material has been studied from several formations on the Pacific Coast. Among these, the faunas of the diatomaceous shales of Lompoc and the clay of Anderson's zone "C" of the Temblor formation near Bakersfield, California, are the best known at the present time. During the coming year the preparation of an account of the Temblor fauna will be undertaken. Considerable attention has also been given to material from the Fernando, Santa Margarita, Monterey, and Vaqueros formations of California. Further studies are in course of preparation on the Calvert fauna of Maryland.

The comparative studies of faunas from Atlantic and Pacific Coast formations which have been made up to the present writing suggest that the data thus obtained will be of considerable value as a check on time correlation between deposits on these two coastal plains. The investigation of the periotic bones of the Cetacea, living and fossil, has been continued with satisfactory results. This problem has occupied more of the writer's time than the other problems which have been undertaken and will require a longer period for completion.

Credit should be given to Mr. Charles Morrice and to Mr. Luke, resident superintendent of the Pacific Oil Company, for their hearty cooperation and for the extensive excavating which has been carried on near Bakersfield in the Temblor formation. The net results of their labors have been the acquisition of at least six species of dolphins, two whalebone whales, one sperm whale, two phocids, one otarid, *Desmostylus*, a sea turtle, and sea bird. Remains of land mammals (apparently a tapir and a sloth) have been found in association with pelagic mammals and sharks. Dr. David Starr Jordan, of Stanford University, has very generously placed the pelagic mammals obtained from the diatomaceous shales near Lompoc at the writer's disposal. Word has just been received that Ira E. Cornwall, Esquire, has decided to deposit his collection of fossil pelagic mammals obtained from the Sooke formation of Vancouver Island, British Columbia, in the U. S. National Museum, where they will be available for study and for comparison.

In closing I desire to express my thanks for the facilities which have been accorded me by Mr. C. W. Gilmore and Gerrit S. Miller jr., curators of their respective departments in the U. S. National Museum.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in palaeontology*. (For previous reports see Year Books Nos. 2-4, 6-9, 11-22.)

No further field work has been done on the fossil cycads, and no laboratory work at Yale during the past year—the condition recorded for several years (cf. Year Book No. 22). The laboratory unit at Oyster River has been in effective use.

One very important addition to the material for the continuation of volume I and II of *American Fossil Cycads* must be noted. This is no less than the historic *Raumeria* (*Cycadeoidea reichenbachiana*) of the Zwinger Museum of Dresden. Recognizing the interest of the results brought forth by the investigation of the American series, the Director of the Zwinger, Professor Riemann, has arranged for the cutting of the best possible wedge from this finest of all European cycadeoids (the wedge carrying, with other axes, the flower-bud illustrated in *American Fossil Cycads*, vol. II, fig. 44). This work is being carried out now, with the further help of the German paleobotanist, Dr. R. Kraeusel of Frankfurt a. Main. The thin sectioning will be done here with also the help of the lens grinders of the Harvey Lewis Company. It is quite the pleasure of a lifetime to record this fine example of international cooperation for the sake of the surest comparisons. The results of the study of the type from the Galician Carpathians must have elemental interest, be they positive or negative—the structures like or unlike those of American types.

One of the greatest difficulties encountered in the elaboration of the cycadeoids is also a difficulty of "the trades" when it comes to the cutting of smaller stone accurately and well. The so-called "diamond saw" which never was well made at best, and yet is nearly indispensable, now costs six or seven times as much as when cutting diamond could be had at about one dollar per carat. Some careful attention has therefore been given to the problem of the diamond saw. Far better saws than have ever been made are a possibility. To make the saws successfully will require a *rolling in* device to secure even and firm embedding of the particles of diamond, without disk warp. This has been thought out in detail, under the advice of an expert mechanician; and as soon as the moderate cost can be met it will be possible to bring the diamond saw back into scientific work and the trades too.

There are other means of cutting petrified material than by the use of the diamond saw, but such are slow and inaccurate. It can be seen that in the study of a group of plants like the cycadeoids the need is thin-sections, and then more thin-sections, supplemented by polished surfaces. After the sections are once at hand it might be said that nine-tenths of the labor of investigation is done. For instance, it was stated in Ward's original description of the species *Cycadeoidea nana* that the type bore indistinct fruit axes. On reexamination this appeared doubtful. But after cutting the type longitudinally and learning the full details of trunk structure, about which nothing was known, and then cutting tangent armor sections covering all of the lateral surface of half the trunk, it was found that this type is really a small branch bearing some 50 peduncles.

Another illustration of the need and meaning of thin-section series concerns a point of primary interest in structural botany. Diligent search has been made for a cycadeoid with extensive development of pitted wood. But no example has been found. The results so far are entirely negative; the cycadeoids appear characteristically scalariform. Meanwhile scalariform wood has been found much more extensively developed in existent cycads than was earlier observed. They have lived much the longer of the two groups and, as Bailey notes, are far more variable in their wood structure than most descriptions imply. The contention therefore that the plastic and primitive element of gymnosperm (and pro-angiosperm) wood, the element that finally changed into the complex of tracheids, fiber tracheids, and vessels of the dicotyledonous woods, *was mainly scalariform-reticulate*, appears more reasonable than ever.

The subject of floral organization in the cycadeoids seems more and more significant, and bettered descriptions have been prepared. Just what may be primitive in flowers in general promises to become far clearer in the light of much needed studies of the histology of present-day flowers, such especially as are being carried out by Professor A. J. Eames of Cornell.

Custodians at the Washburn College, of Topeka, Kansas, have again aided these studies by forwarding the isolated petrified type *Cycadeoidea munita* (Cragin, 1889). This had been lost to view for several years.

One of the fossil "finds" incident to the search for cycadeoids in the Rhætic beds of western Argentina should no longer fail of record. Last year Professor T. D. A. Cockerell, in describing in the American Journal of Science several Dipterans in late Tertiary or more recent amber from Colombia, said "It has long been a matter of regret that nothing was known of fossil insects from South America. It can hardly be doubted that insect-bearing beds will eventually be found in more than one locality."

This remark was doubly justified. The insects in amber had been brought north by E. W. Berry who had also been the first to find insects so fossilized in North America. But earlier still, while searching for plants in the Rhætic of the Andine foothills southwest of Mendoza, a fine insect wing over an inch in length was observed as apparently marking the first fossil insect-bearing horizon of any age in South America. The specimen was reexamined with the help of Professor Petrunkevich of Yale, who knows both the existent and fossil insects so widely. The wing was found to belong to a giant Tipuline; while on the same surface, a few centimeters away, a related dwarf form was to be seen. Both these new generic types appear somewhat primitive as

befits about the oldest-known Tipulids, or more commonly called "crane flies." But as both genera thus fall within or at least near the Tipulidæ they nicely illustrate extreme persistence of type once more.

The great paleobotanic interest of the South American Rhætic has already been emphasized in these reports; but it is also seen that none of the continental areas hold better hope of discovery of insect life of Rhætic times. There are a number of these Rhætic outcrops in Argentina where the shales of fine texture, suitable to both plant and insect preservation in great perfection and detail, invite prolonged exploration. Furthermore it would be just about in Rhætic time that one might look for those clearer records of early hymenopterian life that must be brought to light before any really convincing pictures may be drawn of the environments in which flourished the early flowering plants.

During the past year the Harvey Lewis Company, opticians of New Haven, have again aided in the making of various thin-sections. A few of these are perhaps the finest sections of the petrographic kind ever made. It is at once a good omen and an uncommon pleasure to record such effective help from the trades in the prosecution of pure science.

PHYSICS.

Barnett, S. J. California Institute of Technology, Pasadena, California.
Research Associate in Physics. (For previous reports see Year Books Nos. 19–22.)

Attention was devoted almost entirely to completing the experiments on the magnetization of ferromagnetic substances by rotation, to making experiments subsidiary to this work, and to preparing the complete investigation for publication, all with help from Mrs. Barnett. The work is now in course of publication by the American Academy of Arts and Sciences.

The mean results of this work do not differ greatly from the best of those published earlier (Year Book 1920–1923 and Proc. Amer. Phys. Soc.) for the substances previously investigated; but the new results are more extensive and more precise, and additional precautions have been taken to insure their freedom from systematic errors. The mean specific magnetic intensity of rotation σ (equal, on the simplest classical hypothesis, to the ratio λ of the angular momentum of the elementary magnet to its magnetic moment) is found to be about $1.06 \times m/e$ with an error which is probably less than 2 per cent. The simplest classical theory requires $\lambda = 2 m/e$. Some recent developments in quantum theory (but for comparatively simple cases) appears to favor $\lambda = m/e$; but the phenomena occurring are too obscure to predict with any certainty an exact equality between σ and λ . The discrepancy between σ and $2 m/e$, which we discovered for iron in 1914, is undoubtedly closely related to the anomalies in the complex Zeeman effect, as has been pointed out more than once by Landé.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–22.)

Mr. Carl Barus is completing a report for the Institution which, in addition to the subjects enumerated in the last Annual Report, will contain the investigations more recently undertaken. As these are in considerable variety only a few will be referred to here.

The interference fringes obtained with white light and available for displacement interferometry are usually superchromatics; i. e., fringes in which the dispersion of glass is added to the interferential dispersion. The achromatics, in which the difference of dispersion is effective, are much rarer. It was found, however, that by using the extraordinary ray of a rhomb for calcite, both types of fringes could be obtained successively by changing the angle of the rays passing from end to end of the rhomb with the long edges of the rhomb, through zero. The nonsymmetric distribution of color phenomena so obtained is very striking.

The work on the distribution of acoustic pressure within closed branched or unbranched quill tubes was carried forward. Among the data, the results obtained with a tube system excited by a spark succession is of special interest; for in such cases a new resonance response appeared and proved to be associated with a particular period of the spark succession. It was found that this crest, due to electrical resonance in the sparking apparatus, could be identified among the normal acoustic crests of the tube itself.

Incidental experiments with telephone blown, closed, organ pipes (in which therefore such errors as arise from air currents are eliminated) had shown the occurrence of acoustic attractions and repulsions to be about equally marked. The work eventually brought out that at roughly 2 cm. from the mouth of the pipe and from the telephone plate, the conditions are neutral; or that a movable disk, normal to the axis, if placed there, would remain at rest. Beyond these positions either toward the mouth of the pipe or toward the closed end at the telephone, the disk is attracted (inward); within them it is repelled (outward).

Passing over a number of minor researches, the work recently undertaken treats of the density and diffusion of gases measured by the displacement interferometer. The method is very simple and expeditious and merely calls for the measurement of the small pressure at the top end of a vertical quill tube about 1 meter long, open below, in the lapse of time. Experiments with coal gas, hydrogen, hot air (coefficient of expansion), moist air, etc., have given encouraging results. In the course of the work, however, a discrepancy was detected, showing that about 5×10^{-4} cm. of the pressure to be measured is not represented by the depression of surface of the mercury gauge, but is resisted by capillary or similar forces. Curiously enough this discrepancy is static and appears of about the same strength in the case of relatively high pressures (hydrogen), as well as of relatively low pressure (hot air). It needs further study, as it seems to point to a limit of small pressures measurable by a mercury gauge.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow*. (For previous reports see Year Books Nos. 12-16, 19-22.)

During the period covered by this report, September 5, 1923, to June 30, 1924, moderate, steady progress was made on the investigation. The most rapid progress is normally made each year during the college summer vacation. Such a vacation is not included in the period covered by this report, which is therefore virtually only two-thirds of the year.

At the beginning of the period, the investigation of evaporation by studies on Lake Michigan-Huron and Lake Superior was in progress. The investigation of stream-flow by intensive studies of two small streams in Colorado, at Wagons Wheel Gap, was in progress.

At the end of the period both these investigations were still incomplete, though decidedly satisfactory progress had been made on each. A satisfactory completion of the evaporation investigation was in sight in the near future. The stream-flow investigation was yielding decidedly encouraging results.

Millikan, R. A., Norman Bridge Laboratory of Physics, Pasadena, California. *Research Associate in Physics*. (For previous report see Year Book No. 22.)

The most outstanding results which have been obtained during the past year from researches in atomic structure and radiation carried on in the Norman Bridge Laboratory with the assistance of grants from the Carnegie Corporation of New York may be briefly summarized as follows:

I. The work of I. S. Bowen and R. A. Millikan on hot-spark spectroscopy has been reported in four papers, in which the possibility of definitely stripping from one up through seven valence electrons from the outer shell of the lighter atoms has been demonstrated.

An entirely new method has been developed for identifying the stage of ionization of the atoms giving rise to definite spectral lines.

The whole of the new spectra corresponding to some of these stages of ionization, such as that of B_{III} , C_{IV} , P_V , and S_{VI} , have been fully worked out by both theory and experiment, the two furnishing beautifully checking results.

The important result that the so-called regular and irregular doublet laws, hitherto applied only to X-rays, are valid throughout the whole field of optics has been definitely established.

One of the significant features of these experiments is that they have brought to light serious difficulties with existing atomic theory, thus necessitating a revision of some elements of this theory.

II. The experiments on the penetrating radiation carried on at the top of Pike's Peak by R. M. Otis and Millikan have yielded important results which have been published in several papers. These results appear to require a profound modification of previous views as to the origin of the penetrating radiation.

III. R. C. Tolman and L. M. Mott-Smith have made notable progress in overcoming difficulties which have heretofore inhered in the Tolman method of studying the mass of the electron inside of metals.

IV. In view of recent theoretical and experimental work which has called in question the independence of photo-electric discharges upon temperature discovered by Millikan and Winchester in 1906, J. Rud Nielsen and R. C. Burt have both restudied this question and have both obtained complete independence, the one working with ordinary metals at high temperatures, and the other with alkali metals at very low temperatures. Mr. Burt has shown that contrary results obtained by other recent observers in the case of the alkali metals are due to absorbed gas films. Both of these papers are in press.

V. Messrs. J. A. Becker, E. C. Watson, and W. R. Smythe have brought forth unambiguous evidence of the reality of the Compton effect, having obtained photographs of X-rays scattered by aluminum, which clearly demonstrate that the wave-length of the scattered rays has been increased by such scattering by amounts agreeing within less than 1 per cent with the demands of the Compton equation.

VI. J. Carroll, using Millikan and Bowen's extreme ultra-violet high-vacuum spectrometer, as well as their newly established doublet method of identifying spectral lines, has worked out new optical series in gallium (Ga_{II} Ga_{III}) and indium (In_{II} In_{III}). He is now extending these results to certain other allied spectra.

VII. C. B. Kazda has brought forth the most unambiguous evidence thus far obtained that the detachment of electrons by ultra-violet light is an intrinsic property of each metal and is not dependent upon an absorbed gas film. He has located the long wave-length limit of absolutely clean mercury at 2735 Angstroms. This is the first unquestionably pure metal to have its long wave-length limit accurately determined.

VIII. C. F. Eyring and Millikan have obtained new results on the pulling of electrons from metals by electric fields, and have presented a new theory as to the nature of such electronic detachment.

IX. The Michelson earth-tide experiment set up on the campus of the Institute and operated by Dr. W. R. Whitney has yielded excellent records for the past year, records which show clearly the effect of the change of the loading due to the tides along the coast. The deformation of the coastal strata due to these tides results in a super-position of a new periodic curve upon the lunar tide curve in the pipes of the Michelson earth-tide apparatus.

X. Professor A. Bjorkeson has made the first X-ray analysis with a vacuum X-ray spectrometer of the X-radiations given off by hot sparks. Such sources are found to produce beautiful X-ray spectrograms which should prove of much utility in the analysis of the sources of X-radiations.

XI. R. B. Brode has established with new experiments the reality of the amazing transparency of certain types of atoms for slow-speed electrons. This property, previously shown to be possessed by the monatomic gases, has now been definitely proved to hold for the molecules of carbon dioxide and nitrous oxide.

XII. E. C. Watson has completed the building of an apparatus for the study of the velocities of both Compton electrons and photo electrons as a function of angle. He has obtained preliminary results which indicate that photo electrons show a random distribution of direction. The results with Compton electrons are not as yet ready to be reported.

XIII. P. S. Epstein has published three papers within the year, in which some progress has been made in interpreting both Fraunhofer and Fresnel interference in terms of an isolated light-quant theory instead of a wave theory.

XIV. Richard C. Tolman has obtained important results in his study of the Duration of Molecules in Upper Quantum States (see *Phys. Rev.*, June 1924), numerical values for these durations having been obtained for a considerable number of different molecules.

XV. H. Bateman has published two papers in his now well-known effort to find a new solution to the Maxwell equations which does not involve a contradiction between these equations and the facts of quanta. He has also published two papers on the structure of the electron.

Twenty-five other researches have been actively pursued in the laboratory, some of them of much promise though not yet ready for report.

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports see Year Books Nos. 4-22.)

VISIBLE RADIATION FROM CERTAIN OXIDES.

When a fragment of columbium oxide¹ (Cb_2O_5), which is a white and highly refractory substance, is introduced into a hydrogen flame the existence of two phases of radiation is immediately discernible. These are similar to those described recently in the case of titanium oxide² but are more distinct and pronounced. Within the flame the oxide glows *red*, in the outer oxidizing zones a pale *blue-green*. The sharpness of the transition is most striking.

¹ Through the kindness of Mr. W. L. Lemcke of Franklin, Pennsylvania, the writer received a very pure sample of this oxide, prepared by Dr. Balke of Chicago.

² Nichols: *Physical Review* (2), vol. XXII, p. 42, 1923.

A detailed study of this phenomenon has been completed with the following results:

Phase O (that produced in the oxidizing regions of the flame).—The visible spectrum, while seemingly continuous, is resolved by spectrophotometric measurements into groups of broad, overlapping bands, each presumably consisting of numerous submerged components. The crests of these fall into two sets, the frequency intervals being such as to suggest that the submerged components would be found to conform to the Tanaka interval for columbium. Whether these components can be disclosed photographically remains to be determined; experiments are in progress. That we have to do with a luminescent radiator in the case of phase O is suggested by the usual well-known criteria:

(a) The structure of the spectrum.

(b) The fatigue of the radiating surface, which is very marked during the first half hour of incandescence.

(c) The great excess of brightness of portions of the spectrum over the brightness of the corresponding regions in the spectrum of a black body at the same temperature; an excess which is greatest at the lowest ranges of incandescence and which disappears at about $1,100^{\circ}\text{C}$. (Criterion C is in itself conclusive of luminescence as distinguished from ordinary temperature radiation.)

Phase R (in the reducing flame).—The visible spectrum of phase R on the other hand is *that of a black body*, both as to brightness and as to the distribution of intensities. Superficially, at least while under the action of the flame, *the oxide is jet black* as may be seen by illuminating it strongly enough with white light to quench its incandescence. Under conditions such that portions of the surface are within the reducing region, others without, we have a black region separated from a white one by a very sharply defined boundary; with the apparent anomaly that the *white portions* are glowing much more intensely *than those which are black*.

The darkening of the surface is doubtless due to the formation of the black lower oxide Cb_2O_4 and since under like conditions TiO_2 and Ta_2O_5 also darken in the reducing flame the formation of these lower oxides offers a simple and general explanation of these two phases of incandescence. Preliminary observations indicate that Ta_2O_5 is certainly analogous to Cb_2O_5 in its behavior and a similar study is being made of it.

Neodymium Oxide.—This oxide is notable for the banded character of its spectrum. When used as an activating agent for calcium oxide, a brightly luminescent solid solution is formed, the spectrum of which has been mapped by Urbain¹ and recently studied in much greater detail by Tanaka.²

When this oxide, taken in bulk and not as a trace in solid solution, is heated to incandescence it becomes luminescent at temperatures below $1,000^{\circ}$.³ In view of the fact that the cursory examination made in 1922 showed a spectrum containing bands in the red not revealed in the cathodo luminescence, a further study is now in hand, using the methods applied to the other oxides mentioned above. The bands thus far located by means of the spectrophotometer appear to fall into two sets, having the Tanaka

¹ Little: Inorganic Chemistry, vol. IV, p. 300.

² Tanaka: Journal Optical Society of America, vol. VIII, p. 287 (1924).

³ Nichols and Howes: Physical Review (2), vol. XIX, p. 313, 1922.

mean interval of 18.3. A finer analysis by the photographic method is being attempted.

The luminescence of the group of bands in the red has also been followed in detail between 600° C. and 1,000° C. and has been found to reach a well-defined maximum at about 700° C., at which temperature the brightness is over 800 times that of a black body.

THERMOLUMINESCENCE.

Miss Frances G. Wick, assisted by Miss Slattery and Miss Loh, is investigating the remarkable effect of exposure to X-rays upon thermoluminescence. Certain fluorites and calcites, which are thermoluminescent in their natural state, have their luminescence profoundly modified alike as to intensity, duration, and color by exposure to X-rays before heating. Such substances, after their luminescence has been fully discharged by heating, are restored by the action of X-rays.

The curve for the diminution of the intensity of thermoluminescence with the time, after the crest is passed, is of the same nature as the decay curve of ordinary phosphorescence. By a sufficiently prolonged exposure to X-rays it has been found possible to convert these curves, for thermoluminescence from the *permanent* to the *vanishing* type.

Not all fluorites or calcites are susceptible to X-rays and those affected were such as in previous studies had been found to contain traces of the rare earths.¹ It was shown that pure compounds of calcium could not be rendered thermoluminescent by X-rays, but that after a trace of one of the rare earths or an activating element, such as manganese, had been introduced the material became very susceptible. Thus a sample of CaSO_4 which was entirely inert after exposure, became finely thermoluminescent after X-rays when a trace of manganese had been previously incorporated. Similarly, pure CaCO_3 , artificially prepared, showed no thermoluminescence after conversion into CaO , either before or after exposure to X-rays, but was rendered active by the addition of a trace of samarium.

SPECIFIC EXCITING POWER AND THE LAW OF STOKES.

It was shown some years ago in this laboratory,² in confirmation of the earlier contentions of Lommel³ and of Stenger⁴, that there is a region in the spectrum of fluorescent solutions for which the law of Stokes does not hold; i. e., within which fluorescence may be excited by light of wave-lengths greater than that of the fluorescent light. Professor E. H. Kennard has recently developed a theory of this effect. With the assistance of Mr. L. S. Taylor (Heckscher Research Assistant), he now has in progress an experimental investigation on the specific exciting power of light within these regions, the purpose of which is to test his theory.

In 1922 the writer had an opportunity through the kindness of Professor E. N. Harvey, of comparing the glow produced by the oxidization of luciferin of his preparation with the brightness of various well-known luminescent substances. This is the material to which all known light-giving animals owe their power and it seemed desirable therefore to measure the brightness *in situ* of various marine light-producing organisms.

¹ Wick, F. G.: Physical Review (2), vol. XXIII, p. 296, 1924.

² Nichols and Merritt: *Studies in Luminescence*, Carnegie Publ. No. 152, pp. 1-24, 1912.

³ Lommel: Pogg. Ann. 159, p. 514, 1876.

⁴ Stenger: Wiedemann's Ann. 28, p. 201, 1886.

During April of the present year the diffuse luminescence of sea-water was determined at Sanibel Island, Florida, and from shipboard off the Carolina coast. When compared with the glow from luciferin (16 millilamberts) the intensities observed were very feeble (0.006 millilamberts to 0.0007 millilamberts) but the latter reading was found to be about ten times as bright as a very white shell beach when illuminated by a starlit but moonless night. By the courtesy of the Marine Biological Laboratory measurements of the brightness of *Mnemiopsis leidyi* (0.12 millilamberts to 0.30 millilamberts) of certain dioflagiolates (0.116 millilamberts) and of certain hydroids (0.033 millilamberts) in the harbor at Woods Hole.

MISCELLANEOUS.

The photographic study of the submerged components of apparently continuous spectra has been found exceedingly troublesome and difficult, particularly as to the interpretation of the results obtained. Mr. R. M. Fisher is at work upon this problem from the basis of kathodo-luminescence and Mr. L. J. Boardman from the aspect of incandescence.

Mr. E. E. Wheeler is studying the glow of mercury vapor in vacuum tubes under conditions which give the so-called continuous spectrum of mercury. His method is one suggested by Professor C. D. Child. The study of this spectrum should be very instructive.

SEISMOLOGY.

(For previous reports, see Year Books Nos. 20-22.)

REPORT OF THE ADVISORY COMMITTEE.

The Advisory Committee in Seismology has continued during the year 1924 to follow the definite program outlined in previous reports. To recapitulate very briefly, this program is based upon the assumption that California earth-movements represent mechanical adjustments in a portion of the earth's crust strained by great inequalities of loading, secular contraction, imperfect gravitational equilibrium, and wide differences of temperature gradient. To attain a competent knowledge of these adjustments and so to provide protection against the consequences of a local failure of the structure (earthquake) it is necessary to carry on measurements of the greatest refinement over considerable periods of time (1) of persistent crustal movement or creep, (2) of internal pressures at critical points, (3) of the point (or surface) of origin of tremors, as well as their velocity and the manner of their transmission through neighboring structures. This last will yield indispensable information about the neighboring structures themselves. The method which it is proposed to pursue in search of this information has been indicated in earlier reports.

There has been no occasion to alter essentially any portion of the plan proposed by the Committee at the close of its first year of service, and the advancement of each year since that time has served to confirm the belief that the program, though broad, is thoroughly practical. The participation of the various cooperating agencies has been spirited and whole-hearted, and already very tangible progress has been made. The results of the work undertaken this year will be reported in chapters representing the different activities of the Committee and its collaborators as heretofore.

1. FAULT-ZONE GEOLOGY.

Following upon the publication of the fault map of California by the Seismological Society in 1923, the pressure upon the local subcommittee on California fault-zone geology has relaxed somewhat. Dr. L. S. Noble, of the U. S. Geological Survey, has continued his work in the southern part of the State and has practically completed a geologic map and structure section of the San Andreas rift zone across Rock Creek, San Antonio, and Hesperia quadrangles. The area mapped is a strip of territory 6 miles or more in width along the rift. There is also partially completed a similar map of the rift zone across Elizabeth Lake quadrangle. It is proposed for the coming winter to complete the map of this region from Cajon Pass southward into the Salton Sink. This detailed geologic study of the southern section of the San Andreas rift, which has been carried on for the past three years by Messrs. Noble and Kew, is a chapter of great geologic interest and will presently form the subject of a separate report to be published with appropriate maps by the U. S. Geological Survey. Dr. Noble has also made a reconnaissance traverse of Garlock fault from Randsburg quadrangle eastward to Death Valley. This fault shows recent rift phenomena near Garlock. A report of this traverse also is in preparation.

Dr. W. S. W. Kew, who has been associated with this work for two years past, has severed his connection with the Geological Survey and taken up

private practice as a mining engineer. His continued participation in this work, in which he has had an active share hitherto, will be greatly missed.

It is perhaps not within the province of an official record of the work of the Committee to include activities in which it has had no direct share, but it is a matter of more than passing interest, whether suggested by the various activities set in motion in California by this Committee or not, to note the assignment by Professor Tolman of 30 students from the Department of Geology of Stanford University to study each a section of the San Andreas fault in the vicinity of Palo Alto as a part of his summer program of field work. This work will no doubt be published collectively in due course and contribute very substantially to the advancement of our knowledge of the rift geology of the coast region.

2. ASTRONOMICAL MEASUREMENT OF CRUSTAL CREEP.

Inasmuch as position measurements upon the earth from observations of favorably situated fixed stars may be in error by as much as one meter, a slow and small crustal movement will escape detection unless such measurements are continued under like conditions for long periods of time. It is therefore a great pleasure to be able to announce that provision has now been made for the continuous operation of the Ukiah Observatory by the U. S. Coast and Geodetic Survey. Our attention was sharply drawn to the importance of such measurements for the study of cumulative crustal strains (creep), at the very beginning of the studies inaugurated by the Institution. At that time their continuation was deemed somewhat precarious because of minor international complications, but that limitation is now happily removed.

The participation of Lick Observatory in these measurements has been somewhat delayed by disappointments connected with the building of a special telescope for the purpose, but it is hoped that these difficulties also may soon be overcome.

3. SURFACE DISPLACEMENTS.

The continuation during the past year of the primary triangulation by the U. S. Coast and Geodetic Survey is still of the greatest interest. A second appropriation of \$15,000 was available for this work and splendid progress was made. Beginning at the point where the work of the previous season closed (Mount Hamilton) the triangulation was continued southward along the coast to the Santa Barbara Channel, where the persistent fogs made it unprofitable to continue work in mid-summer. The Survey party then moved south to the Mexican boundary and continued their operations northward from there, leaving unfinished a gap of about 50 miles, which requires to be filled this year to complete the system of triangles from San Francisco to the Mexican boundary.

The program for the present season contemplates filling this gap and then continuing eastward through San Jacinto and Cuyamarcá to American Peak, Kofa, and Powell in the Colorado River Valley. The completion of these triangles will provide a reasonably complete network of points of reference through which to determine future movements in the immediate coast region, tied fast at its southern extremity to the stablest region available in the southwest (the Colorado River Basin).

In view of the displacements in the Great Basin, to which attention has recently been called in the publications of Professor Louderback, it would

somewhat strengthen our knowledge if the northern base points, Lola and Round Top, could be further fixed in relation to points east as well as west. It would also be advantageous for reasons connected with the geology of the region if a line of triangles could be extended northeastward from Los Angeles to stable points beyond the Inyo County fault zone.

Whether these additions to the system, as originally laid out, can be made a part of the present plan can not at the moment be determined. The appropriation available for this purpose was cut from \$15,000 in 1923 to \$12,000 in 1924, and may not prove adequate for any extension of the original program, even though such extension appears vital to the original purpose, namely, to provide a fixed network so complete that any earth-movement in the California zone may be established in direction and magnitude without fear of misinterpretation.

In view of the fact that any incompleteness in establishing this reference network may have the effect of casting doubt upon all precise conclusions respecting future earth-movements in this region, just as uncertainty in the position of the Mocho-Diablo base-line clouded the conclusions respecting the movements of 1906, the Carnegie Institution determined to supplement from its own funds the appropriation available to the Survey this year in order to include within the network the Ukiah Observatory and the stations north of San Francisco Bay which were occupied in 1906-7. This addition to the plan will be completed during the present summer.

By way of emphasizing the enormous importance of this system of triangles in any competent study of the earth-movements of the region, it may be noted that northward displacements have already been established by the triangulation so far completed, amounting to as much as 25 feet for certain points west of the San Andreas fault since the last previous survey some 30 years ago, while points east of the fault have been displaced by different amounts and in other directions. Displacements of this order of magnitude, if confirmed by the work of the present summer, indicate that we have in this region not only a problem of great economic and social importance to the inhabitants of the region, but also an active field for investigation in which displacements are occurring of such magnitude that they can be competently studied in the time available for individual human effort. It is the view of the Advisory Committee in Seismology that this latter factor is of outstanding importance in determining the course of action of the Institution and the group of scientific organizations associated with it, respecting the continued study of this group of seismologic problems.

4. PUBLICATIONS.

Toward the close of the year, specific recognition was given to the successful progress of these studies of earth-movements in the form of a special grant of \$5,000 by the Carnegie Corporation of New York, in the following terms:

Resolved: That the sum of five thousand dollars (\$5,000) payable June 30, 1924, be, and it hereby is, appropriated to the Carnegie Institution of Washington for seismological publication.

Thus provision is made for the adequate publication of the new work in seismology which may result from the impetus now given to the subject in this country by the cooperation of so many effective agencies.

It is not the present purpose of the Committee to inaugurate a new series of publications for this purpose, but rather to centralize publication, so far as

may be, in existing agencies, by giving appropriate aid to the Bulletin of the Seismological Society of America, which cooperated with us so effectively in the publication of the fault map of California.

5. THE DEVELOPMENT OF INSTRUMENTS.¹

Five experimental seismometers have been tested and operated over considerable intervals during the past year.

A short-period instrument, designated A, with free period of about 0.8 second, damping factor of 0.2 on a scale on which 0 corresponds to no damping and 1 corresponds to critical damping, and a static magnification of approximately 1,200, was already in operation in the basement of the Observatory office in August 1923. It had then been recording for 2 or 3 months, and it was continued in use until the middle of January 1924. This was only partially oil-damped to minimize "violin-string" vibration, and so suffered considerable undesirable disturbance from very local artificial causes.

A short-period instrument, designated B, had, at the end of August 1923, been very recently installed in the Norman Bridge Laboratory of Physics at the California Institute of Technology, and with a few brief interruptions this has been in operation throughout the interval under report. This has a free period of about 0.8 second, and a static magnification of about 2,500. Rough tests indicate a damping factor of the order of 0.2. It also is only partially oil-damped.

Beginning early in October 1923, a short-period instrument, designated C, fully oil-damped, was operated in the basement of the Observatory office until the middle of March 1924. This had a free period of about 0.8 second, a static magnification of about 1,200, and a damping factor of about 0.3. Because of its better oil-damping, local disturbances had little undesirable effect on this.

Late in February 1924, a short-period seismometer, designated D, was installed in the basement of the Observatory office, taking the place of A. Many improvements were embodied in the construction of this instrument, including leveling screws, adjustability of the damping magnet, a device to aid in determining the free period, a convenient torsion head, a method of clamping the suspended system, and the addition of a meter-focus concave mirror to replace the exterior lens and double the static magnification. It is considered that this design will require little or no modification. This instrument has been operating ever since its installation, with a free period of about 0.8 second, nearly critical damping, and a static magnification of 4,000 to 5,000 not yet precisely determined. It is fully oil-damped and this minimizes to a very marked degree its undesirable responses to local disturbances. Its performance has been very satisfactory. However, owing to its high static magnification, the recording point of light is required to move very much more rapidly over the surface of the photographic paper in its to-and-fro excursions when an earthquake is being recorded than it does when the seismometer suffers no disturbance; consequently, if the strength of the light-source is not too great for the steady, quiet condition, under-exposure results when earthquakes of moderately large seismographic amplitude are being registered. This, in general, is an unavoidable condition with photographic recording. Somewhat to mitigate it, a much more brilliant light-source is

¹ Extract from the report of H. O. Wood, Research Associate in Seismology.

used and to prevent over-exposure during the usual quiet operation a slotted disk is rotated in front of the light beam. Then when to-and-fro excursions of the light-point are produced, their track is indicated by lines of separated dots adequately exposed if the amplitudes do not become too great, while in ordinary running these dots coalesce to form a line of ordinary strength. This expedient was resorted to in April 1924 and it has been working fairly well ever since; but to be completely satisfactory this attachment needs further development.

Beginning in March 1924, a long-period torsion seismometer, designated E, was installed in place of C, and tested. The free period was given several different values, ranging from about 5 seconds to more than 15 seconds, while the corresponding damping factors ranged from conspicuous underdamping (about 0.5) to considerable overdamping, the value of which was not determined precisely. During subsequent steady operation the constants have been: free period about 10 seconds, damping very nearly critical, with a static magnification of about 300. This instrument, though lacking in convenient attachments for adjustment and control, and installed under very adverse conditions for routine operation, has behaved admirably as a teleseismic recorder and there has been comparatively little confusion from tilting or temperature change.

It has been shown conclusively that short-period local earthquakes are registered best by the short-period instruments, with damping near to or just below the critical value. Moreover, and this was not at first anticipated, the first phases of teleseisms usually have been registered best by such instruments, sometimes very strikingly so, since it has often been true that a short-period wave-train has been an important component of the phase. But to delineate the long-period waves of the third phase of teleseismic disturbances with appreciable seismographic amplitude, a long-period instrument is required, since the dynamic magnification decreases to a very low value when the period of the disturbance is long, relative to that of the instrument, even when the static magnification is very high. To cite illustrations—we registered, with vigorous indication, not only the first (and second) phases of the great Japanese earthquake of September 1, 1923 (August 31, P. S. T.), but also at least 6 first-phases of after-shocks within 12 hours, with several in addition during the next day or two. So far as the writer is informed this is quite without precedent; and it is due to the special suitability of the short-period, critically damped, high-magnification instruments to respond to and register short-period disturbances, even of very small amplitude. While, in contrast, a major teleseism was registered finely late in June 1924, with the long-period, relatively low static magnification instrument, which exhibited clearly long-period surface waves that had traversed the major arc of the earth's circumference and others that had traversed both the minor arc and the complete circumference in addition. This, of course, has been observed many times before with long-period seismographs.

Many of the shocks of local and regional character registered have exhibited normal phase development, but a considerable number of others have developed phases (pre-phases) which probably have not been recognizably registered hitherto. The registration of this very small earlier motion is probably made possible by the frictionless operation and very high static magnification of the torsion seismometers we have employed. It is gratifying

to have phenomena which are probably new thus brought to light—though new problems, concerning the interpretation of the seismogram and the application of seismometric measurements to the triangulation of shock origins, are raised thereby.

A great many local earthquakes have been registered during the period under report. Shocks of local character have been registered at all distances from Pasadena, from a very few miles up to 300 miles or more. But a majority of those registered have originated at distances between 25 and 200 miles, on the basis of present formulas for distance determination.

Normal microseisms have been registered, especially with the long-period apparatus, but they have been of small seismographic amplitude for the most part.

An interesting result was the registration, both at the Observatory office and at the California Institute of Technology, of vibration caused by a badly-installed, heavy, reciprocating steam engine, operating sporadically in the southern part of Pasadena, distant about 2.2 miles from the Observatory office and about 1.5 miles from the California Institute. The motion was registered as a regular, sharp-peaked, zig-zag "sine-curve" with 120 cycles to the minute; and the seismographic amplitudes at each station corresponded well with the static magnifications and distances.

Two great blasting operations have been carried out in Southern California during the interval under report. The first of these, on the Palos Verdes project near Point San Pedro, set off a charge of 115,000 pounds of black powder, practically all at once. This was registered by instrument A but the record was not well characterized by phases. The distance from the site of the blast to the station was about 49 kilometers. For practically the entire distance the rock at the surface was either recent alluvium or sedimentary material of different ages, but all comparatively recent. However, granite is considered to underlie all this region at a depth of the order of a mile.

The second great blast was fired in hard and relatively fresh rhyolite of the quartz-porphyry type at a place a little southeast of Corona, distant about 67.5 kilometers from the station at the Observatory office. The intervening surface geology can not be described briefly. Granite is believed to lie below. Approximately 182 tons of high-grade dynamite were detonated as a single charge. The time of firing was determined accurately and the timing of the seismograms was checked adequately. Good records, easy to interpret, were written by the high-magnification, short-period apparatus at both the Observatory office and the California Institute stations. Also a very definite record of small seismographic amplitude was written by the long-period, low-magnification apparatus. The results afford new and valuable data upon which to base estimates of the rate of transmission of elastic waves in the crust of the earth. The discussion of these records will form the subject of a brief paper.

The experience of the year, both with natural earthquakes and with artificial vibrations, indicates that stations need not be spaced so closely as 50 kilometers to form an adequate network for seismic triangulation, but it is too early to say how great the minimum distance ought to be.

Experiments indicate that a torsion-suspension vertical-component seismometer with a free period of 0.5 second can be operated successfully, and damped critically by magnetic means. But for free periods of several seconds, the angle of stability for such an instrument is very small, and in all cases

where gravity is balanced by a spring-suspension, whether torsional or not, there is an instrumental "disturbance" which can not be eliminated. Further experiments are in progress to obviate these difficulties.

6. OBSERVATION STATIONS.

With the development of successful instruments for the study and location of earthquake tremors, some provision requires to be made for appropriate stations in which this apparatus may be mounted, and for a central station, where the records may be brought together for study and pertinent research work undertaken in the development of the general project. Some allusion has been made to such an organization in previous reports, but no active step was taken pending the successful operation of the new instruments.

The tentative arrangement, now under consideration, contemplates a central laboratory to be located in Pasadena, most appropriately in close relation with the California Institute of Technology, whose staff includes men of especial distinction in subjects allied to geophysics. In such a laboratory it would be a part of the immediate program (1) to make application of apparatus already developed for the study of tremors, (2) to develop further apparatus for the study of tilting or other continuous movements through which stresses accumulate locally and find release presumably when the elastic limit of the rock structure is reached.

Outlying stations would mount accessory instruments in positions determined by the known character and weaknesses of the structure, and the locations of these may be changed from time to time as our knowledge of the structure increases. At the moment the locations contemplated are (1) Mount Wilson Observatory, (2) the Citrus Experiment Station at Riverside, (3) the Scripps Institution at La Jolla, and, if suitable arrangements can be made, an appropriate location at Fall Brook and on Catalina Island. These to be in addition to the central station at Pasadena. Apparatus for the equipment of these stations is already under construction.

7. SOUNDINGS.

During the past year the Hydrographic Office of the Navy Department has found little opportunity to continue deep-sea soundings with the new sonic sounding device, but has shown its continued interest by two undertakings of great importance not only for the information secured, but for the development of the sounding device itself. The Cruiser *Milwaukee* was equipped with the sonic sounding device during its trial trip from Seattle to Sidney, Australia, over a course which included some of the great deeps of the Pacific Ocean. Soundings were continued throughout the entire cruise from Seattle direct to Sidney and on the return journey by way of the Hawaiian Islands. In view of the fact that these soundings were usually made at intervals of 10 minutes, a nearly continuous section of the Pacific Ocean along the course indicated has been developed and will no doubt eventually be published by the Hydrographic Office in regular course.

It is a rather interesting fact that in the greatest deeps a number of observations were missed. This may of course be due to the fact that the capacity of the instrument in its present form had been over-reached, but it is much more probable that the deposits of ooze characteristic of these extreme depths offer no definite surface of reflection for sound waves, an observation which perhaps has never been made before.

On the return journey the *Milwaukee* was charged with the task of making a systematic group of soundings in the quadrant southeast of the Island of Hawaii, from the shore line out to the unbroken ocean floor (about 2,700 fathoms). These observations developed the important fact that there appears to be no conspicuous fault or volcanic structure southeastward of the Island group in the direction in which such features might be expected.

During the year there have been published also the charts of sonic soundings taken by the *Stewart* on her voyage from Newport to the Philippines. The published charts include a section of the Atlantic Ocean from Newport via Azores to Gibraltar thence through the Mediterranean via Malta to Port Said and from the Gulf of Aden via Colombo to the Straits of Malacca. Publication of the remaining soundings from the Straits of Malacca to Manila and thence to Hongkong will doubtless follow.

In connection with the development of the sonic sounding device it is of importance further to note that the U. S. Coast and Geodetic Survey has mounted one of the Navy instruments on one of its vessels, the *Guide*, and has given several months of intensive study to the sources of error to which the instrument is liable and the possible precision to be attained with it. From this study it appears that results correct within 1 per cent by this method of sounding are easily and uniformly obtainable; indeed it is probable that the accuracy of the depth measurement is now greater than the accuracy of the position measurement at sea. It is to be hoped that the U. S. Coast and Geodetic Survey will take an early opportunity to publish the results of these studies, which are of the utmost importance for future contour mapping of the ocean floor.

8. RECOMMENDATIONS.

It is recommended that:

- (1) Provision be made for further experimental and construction work on vertical-component instruments for the stations already designated.
- (2) Provision be made for the further study of minute-to-minute time signals for simultaneous record at all of the stations.
- (3) Provision be made for further experimental work in the study of cumulative stresses (tilt mechanism).
- (4) Provision be made for adequate laboratory equipment and furniture for the central station in Pasadena.

In view of the very effective character of the present cooperative organization no changes are recommended in it. Your Committee continues more than ever sensible of the splendid spirit shown by the organizations participating in this enterprise, and believes that through this means a problem, baffling, at first, in its complications and somewhat overwhelming in magnitude, will prove capable of at least partial solution.

J. A. ANDERSON,
RALPH ARNOLD,
W. W. CAMPBELL,
ARTHUR L. DAY (*Chairman*),
A. C. LAWSON,
R. A. MILLIKAN,
HARRY FIELDING REID,
BAILEY WILLIS,

Advisory Committee in Seismology.

CARNEGIE INSTITUTION OF WASHINGTON,

August 1924.

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